OCEANOGRAPHY
The Ten Years Ahead

A LONG RANGE NATIONAL OCEANOGRAPHIC PLAN 1963 - 1972

INTERAGENCY COMMITTEE ON OCEANOGRAPHY
of the
FEDERAL COUNCIL FOR SCIENCE AND TECHNOLOGY
United States of America

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FOREWORD

The Interagency Committee on Oceanography of the Federal Council for Science and Technology has since 1959 been coordinating the annual plans and programs of the federal agencies in the marine sciences. During this time the need to view agency plans and their implications on a more extended time scale has greatly increased, especially considering the continued growth of federal support for science and the consequent sharpening of the competition for such resources as skilled manpower and funds. This long-range plan is designed to meet this need.

Until very recently the pressure of this competition has kept oceanography in a comparatively primitive state with respect to resources, activity, and accomplishment. With the completion of studies both inside and outside of government, a widespread conviction developed that the national interest demanded more rapid growth. Sharply accelerated support during the last three years has now brought oceanography to a level from which our planning for the next ten years can be projected in balance with all of science and technology supported by the government, which shows signs of doubling over the next ten years.

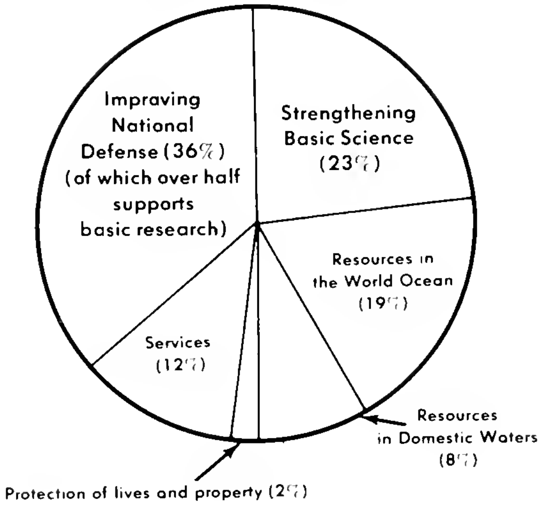
To be effective these expenditures require comprehensive and farsighted plans, taking account not only of the relationship between scientific discovery and application, but also a desired balance of effort among the various scientific disciplines and among institutions in universities, industry, and government who perform this research. And as these relationships become increasingly well understood, it will become ever more important for those working in one field to become aware of plans being made for others. In this way they will be able to participate more effectively in the pursuit of broadly shared objectives.

This Long-Range National Oceanographic Plan has therefore been drafted within the framework of a statement of national goals. This and the long time scale on which the effort is discussed should facilitate the appraisal of the shorter term steps to be taken along the way. The rapidity with which the oceanographic program has grown and the large number of federal agencies involved makes such appraisal both difficult and necessary, to determine its consistency with other indices of the national interest such as congressional resolutions, aims enunicated by the President, and goals established by the Federal Council for Science and Technology. *It should be emphasized that although the benefits of our program are intended to accrue to the Nation at large, the effort described herein is limited to that sponsored by the Federal Government itself.* That is, this plan represents a federal effort to further national goals.

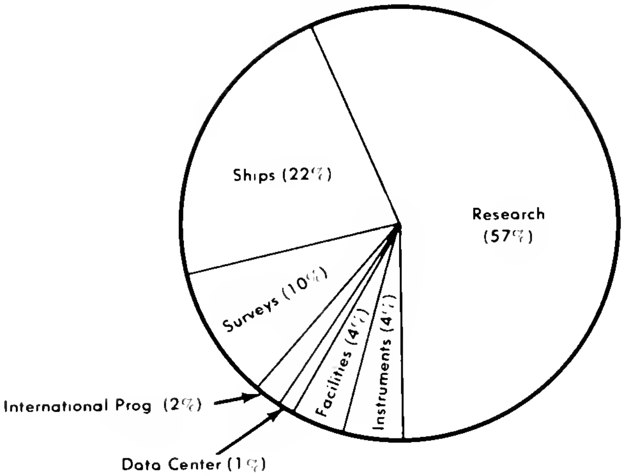
This federal funding not only supports oceanographic activity in federal agencies but even more extensive programs in private institutions as well. The Interagency Committee on Oceanography has endeavored to express in this document the means through which federal, academic, and industrial members of the oceanographic community can look ahead together.

Finally, it should be noted that this plan is a statement of our needs and aspirations. It is in no way fixed or irrevocable. It must be expected to change year by year as new scientific results and new technological opportunities become available, and new requirements or priorities develop. A measure of its success will be the extent to which it fosters progress toward the solution of many of the problems of seeming importance today, while providing an enhanced capability to meet shifts in priorities and the opening of new paths toward our national goals which may take place tomorrow.

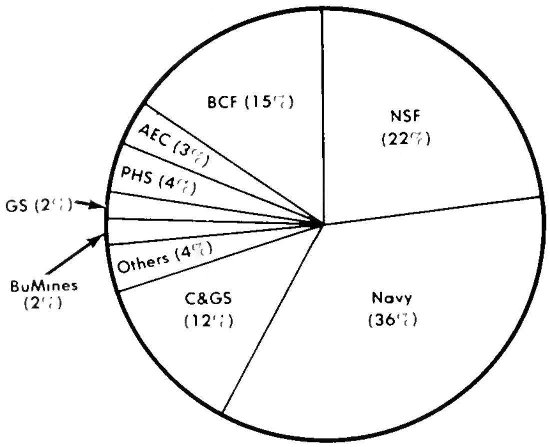
BREAKDOWN BY GOALS



BREAKDOWN BY ICO FUNCTIONAL AREAS



BREAKDOWN BY AGENCY



Others
- Coast Guard
- Weather Bu.
- Bu. Sport Fisheries & Wildlife
- Office of Ed.
- Smithsonian Inst.
- Army
- Maritime Ad.

Frontispiece - National Oceanographic Budget for the Ten-Year Period — $2.323 Billion

A LONG RANGE NATIONAL OCEANOGRAPHIC PLAN 1963 – 1972

SUMMARY

This Nation's destiny and the sea have been significantly linked together since the day this country was discovered by seafaring men. During this Nation's early growth, the sea provided both a natural barrier to aggression, and a highway for world-wide exchange of goods and of culture. Later on, the Nation's interest in and dependence on the sea waxed and waned. During World War II, it was stimulated by the offensive and defensive manifestations of undersea warfare, and attention was focused even more sharply on submarine warfare when nuclear power suddenly cast the entire ocean, from bottom to surface, as the arena for warfare. The POLARIS system was a natural evolution of this new technique as a new, virtually undetectable, form of deterrent.

Simultaneously, late in the decade of the fifties, came a new appreciation of the potential of the ocean's abundant fish stocks to feed undernourished peoples of the world. Also, the new era of scientific exploration revealed oceanography lagging significantly by comparison to rapid growth in sister fields. But to achieve these objectives for security or for peaceful exploitation of the ocean greatly increased knowledge was required of the sea itself, its contents, its boundaries, and its interaction with the atmosphere. Federal agencies having oceanography-related missions requested the National Academy of Sciences to undertake a comprehensive study of the opportunities of science to contribute to man's understanding of the unseen 72 percent of the planet. With the 1958-59 publication of the NAS reports, both the Executive and the Congress recognized "inner space" to be a challenge deserving of enhanced support.

Federal budgets have grown from $24 million in FY 1958 to $124 million in FY 1963. Equally significant, oceanographic research, which is a concern of some 20 separate agencies, began in 1959 to be planned on a Government-wide basis. Scope and effectiveness of joint planning and conduct of research have kept pace with growth in research, and since FY 1961, these plans have been published as "National Programs" annually developed through the Interagency Committee on Oceanography.

As valuable as have been these yearly programs in guiding developments by constituent ICO agencies and in providing a coherence to activities of the scientific community that conducts much of this research, there has been a growing need for a perspective in which the oceanographic programs of various federal agencies over the next decade can be more clearly seen in relation to each other, and especially in relation to the national goals which they support.

This plan is now complete—neither as a rigid blue print to be followed slavishly, nor as a single master document. Rather, it is a restatement of national objectives that depend on oceanography, an assignment of relative priorities expressed in terms of levels of activity associated with these different goals, a projection of the growth necessary to achieve these goals, expressed in terms of required research resources—funds, manpower, and facilities. These requirements are expressed in contemporary terms, but with intention of flexibility that reflects an accommodation, even an integration, of new technologies of instrumentation, deep diving vehicles and data collection systems that will make the conduct of oceanography of the seventies far different from that of the sixties.

Finally, the plan establishes the different roles of federal agencies who participate in these programs, with changes in their programs that are more than a simple linear expansion of present activity.

This report, incidentally, anticipates the preparation of additional "satellite" reports—projecting in more detail plans for specific scientific objectives, plans for individual agencies and research institutions, but all presumably related to a common goal: The national goal in oceanography: *To comprehend the world ocean, its boundaries, its properties, and its processes, and to exploit this comprehension in the public interest, in enhancement of our security, our culture, international posture, and our economic growth.*

These projections required certain basic assumptions in planning—first, that annual growth in manpower over the next decade will average 9 - 10 percent compared to about 7 - 8 percent in all fields of science and technology as a whole. Oceanographic budgets will grow about 10 - 11 percent annually on the average. For oceanography, the growth is expected to be about in pace with the national average for all of science and technology, faster during the next five years than in the subsequent five years, with annual expenditures rising to $350 million in FY 1972.

The greatest rate of increase in funding must occur during the early part of the period when the need to replace obsolete and inadequate oceanographic ships is greatest. The net growth in the size of the fleet is kept proportional to the growth in manpower while facilities are expected to grow primarily in size rather than in numbers.

Some major changes in emphasis within the overall program are projected. The proportion of the total effort which is devoted to research should be markedly increased, as should that directed to exploiting and managing oceanic resources and controlling pollution and threats to health. The fraction devoted to defense and to routine surveys and services, while remaining a major effort, is expected to decrease although the absolute amounts will rise. Efforts on behalf of protecting life and property along seacoasts and in promoting the safety of operations at sea should remain relatively unchanged.

The greater emphasis on research reflects a general consensus that applied work demands a firmer footing on theory and empirical observation and broad understanding than now exists to permit even narrow questions of practical importance to be answered properly. Moreover, research conducted within the context of any single goal or agency mission by its nature contributes to the general pool of knowledge and inevitably finds application to other problems in other agencies. The Navy will continue to devote its oceanographic budget to research in areas of immediate and potential importance to defense, but much of this research has nonmilitary implication; the Bureau of Commercial Fisheries will devote almost two-thirds of its growing program to basic studies, and the National Science Foundation is expected to increase its program almost fourfold. All told, about 56 percent of the projected effort over the decade will be basic research, with broad though incalculable implications for the applied work of all agencies in support of every national goal. The program in support of basic oceanography is divided as follows:

SUPPORT OF BASIC SCIENCE; 1963-1972
(56 Percent Total Budget—$1300 Million)

	(millions)
Navy	$ 465
National Science Foundation	500
Bureau of Commercial Fisheries	200
Geological Survey	40
Atomic Energy Commission	30
Public Health Service	30
Smithsonian Institution	25
Coast and Geodetic Survey, the Weather Bureau, the Bureau of Mines, the Bureau of Sport Fisheries, the Maritime Administration, and the Coast Guard.	10

About 32 percent of the total budget consists of programs with direct application to other national goals. It is divided as follows:

SUPPORT OF APPLIED OCEANOGRAPHY
(32 Percent Total Budget—$750 Million)

	(millions)
The direct support of defense projects	$ 370
Problems of resource management and the control of health threats in the world ocean	190
Exploiting resources on and under the continental shelf	70
The protection of the U.S public from local pollution and unfit seafood	70
Protecting life and property along the coasts and enhancing the safety of operations at sea.	50

The remaining 12 percent ($280 million) of the budget supports routine surveys and services of general utility to the entire oceanographic community.

Most of this effort is also highly beneficial to private groups with a special interest in the sea. Much of it is considered essential to the fishing industry, helpful to the shipping and recreation

industries, desirable for the mining industry, and indispensable to the oceanographic scientists themselves. The oil industry has traditionally supplied its own oceanography.

The new capabilities and systems to be purchased during this decade include 85 to 97 new research and survey ships (about 52 will be additions to the fleet, and the remainder replacements for vessels now in operation) six to eight submersibles for the exploration of depths from a few to 18,000 feet, and one designed for 36,000 feet; approximately 12 new major government oceanographic laboratories or facilities, plus underwater experimental installations for mining on the continental shelves.

Possibilities which may be added to these include:

An operational oceanographic forecasting system for general use;

Automatic recording and telemetering buoys for ocean surveys;

Additional meso- and bathyscaphs;

Operational fish farms; and

Radically new fishing vessel designs and equipment.

Based on the current manpower projection, the ten-year comparison in capabilities and systems is planned to appear as follows:

	1963	1972
Ships	76	128
Major Laboratories	over 50	over 70
Professional Manpower	2700	over 6000

The extensive ocean survey program on which the United States has embarked can be enhanced by international cooperation. The Intergovernmental Oceanographic Commission (IOC) of UNESCO is undertaking to organize this cooperation, as it has the International Indian Ocean Expedition and the Tropical Atlantic Investigations, both of which the United States supports. Even the five largest oceanographic nations—the U.S., the USSR, Japan, the United Kingdom, and Canada—cannot support individual efforts capable of meeting all their own needs and will find it advantageous to pool their efforts with each other and the 39 smaller members of the IOC for many desirable programs.

The United States organization for coordinating federal efforts in oceanography, the Interagency Committee on Oceanography of the Federal Council for Science and Technology, needs strengthening to meet its growing obligations. It should add a small full-time analytical staff to its present Secretariat, and funds should be provided for studies, where necessary, to draw on competence outside the Federal Government. Otherwise, many of the approximations and value judgments which, with time and effort, might have been made more exact and objective in this plan will remain to hamper future planning, and the consequences for the planned program of unexpected setbacks and unforeseen opportunities which will inevitably occur in the future may not be seen quickly and clearly enough to permit an optimal accommodation.

Chapter I
INTRODUCTION

Three questions have been examined at the outset before proceeding to the plan itself. They are:

Why is this plan needed?
For whom is it written?
What is it supposed to do?

A. Why a Long-Range Plan?

This plan is needed for two reasons. The first is to provide a perspective, both over the field of oceanography as a whole and over the time period ahead, within which the relationship of the highly varied and diverse activities to each other and to the overall effort can be seen. The second reason is to assure that this overall effort is responsive to the national interest.

Perspective is needed because oceanography, always a complex of pure and applied programs in a variety of disciplines involving numerous institutions, has grown so rapidly during the past five years that it is increasingly difficult for people concerned with one aspect of the field to be well-informed about work being carried on elsewhere without a plan and without the coordination afforded by a plan. The danger is that inadvertent duplication and waste of effort will occur on the one hand and, far more likely, that opportunities for joint large-scale efforts which could tackle problems beyond the scope of individual agencies or laboratories will be overlooked on the other. Furthermore, though primary support for oceanography now comes from the Federal Government it is applied through some 20 separate offices and bureaus, each charged with a different basic mission. Oceanography, though still small compared to many other programs, has now become large enough to have to face up to one of the requirements associated with size, diversity, and a common source of support—the requirement for centralized planning.

Such planning is all the more important in terms of making most effective use of research resources when considering that oceanography is small with respect to some indices of its practical importance. The burgeoning world population, particularly in the underdeveloped areas, makes the oceans with their huge and inefficiently exploited food resources of inevitable and increasing value to humanity as a whole. Questions of how to manage this resource wisely and well can only be answered in the international arena, since the fish of the sea acknowledge no national boundaries. Oceanographic knowledge and understanding is essential if valid purpose is to enter our approach to such management.

Other indices of the strategic importance of the oceans are becoming ever more clearly recognized. The cloak of concealment provided by a medium which is virtually opaque to all forms of energy except sound is of immense military significance. For example, it permits us to deploy the Polaris submarine system, a component of our deterrent forces which is virtually nonpreemptable, and thus to reduce the temptation a would-be agressor might otherwise feel to launch a surprise attack on our complex of retaliatory weapons systems. Further understanding and exploitation of both the defensive and offensive potentialities of underwater sound transmission and related ocean phenomena is then a clear military necessity.

Other aspects of the oceans affecting all or large numbers of us in common include the health hazard posed by pollution from industrial wastes such as oil, chemicals, sewage, etc. and from radioactive substances; danger to life and property from waves and flooding; risk to shipping from floating ice, storms and navigational hazards; and threats to resources such as the recreational value of the seas which should be common property. Again, our programs in these areas must reckon with the policies and actions of other nations and be motivated by a concern for the public good.

There are, of course, many special groups within the Nation that are concerned with oceanography in their own behalf, without explicitly equating their interest to that of the Nation as a whole. Fostering their healthy development, subject to normal political, social, and economic constraints, is almost a definition of the national interest. The fishing industry, the shipping industry, mining and oil industries, and in a sense the scientific community, are among the groups in our society for whom the oceans have a special significance. Though the benefits accruing to these segments of the Nation through federally supported programs in oceanography cannot be

measured in precisely the same terms as the benefits accruing to the Nation as a whole, these benefits are obviously related and overlapping. This is clearly the case with the scientific community whether in private or government employ. The scientist by satisfying his curiosity and desire to understand provides at the same time the knowledge by means of which strategic, military, economic, and commercial goals related to the sea can be achieved. And by satisfying their more special goals, the military, economic, and commercial sea-going activities support each other with tools of various kinds, engineering developments, facilities, and platforms and together make possible the furthering of scientific as well as national goals. Nevertheless, the national goals are not merely the sum of the special interest goals, They are rather those goals like the preservation of peace, the extension of the rule of law and justice, the maintenance of a strong economy, and the safeguarding of health, property, and resources held in common which must be achieved to permit the full realization of the goals held by individuals and special groups which constitute our society.

A centralized plan is therefore needed because of the size, complexity, and importance of the field and the fact that its growth, by being so sensitive to decisions made at the federal level, introduces considerations of the national interest.

B. For Whom is it Written?

This plan is written for the information of all those interested in the nature, scope, and growth of oceanography in the United States. Most particularly, it is hoped that this information will be of interest and assistance to those people working so actively in one aspect of the field that they have difficulty seeing their work in relation to that of others.

It is written for the Congress. The appropriations required for the execution of the plan developed here come from the Legislative Branch, and it is of basic importance that a clear explanation be made of the objectives and projected means for their achievement for which support is solicited. It is hoped that this document fulfills this important purpose.

Finally, it is written for those in the Executive Branch who must make decisions within their own spheres of responsibility regarding the implementation of the plan outlined here. It should be emphasized that this plan is not a decision in itself; it is a basis for decision. It presents from the national viewpoint the goals and the capabilities required to achieve these goals, indicates the nature of the systems, forces and relationships required to provide these capabilities, and points out the direction which must be taken by research and development to remedy deficiencies or exploit as yet unrealized but exciting potentialities in these systems and forces. It does so, however, only as a first approximation and acknowledges numerous alternatives and contingencies. Much of the information needed to resolve the many uncertainties contained herein lies either concealed in the future or inaccessible at the time of writing.

C. What is this Plan Supposed to Do?

Many of the decisions made in oceanography not only have long lead-times before their results are apparent, but also have consequences and implied commitments which, when once felt, extend over very long periods. For example, it takes as much as four years from planning to completion to build a major oceanographic research or survey ship, and perhaps 20 or 30 more to wear it out. Expeditions take many, many months to organize, several years to carry out, and their findings may change the world for all time. The real worth of such decisions cannot be seen except from the long-range viewpoint, and one of the functions of this plan is to portray as clearly as possible the consequences of present and contemplated commitments of this sort. Further, this type of planning must be accomplished with particular care, since expeditions are expensive and research manpower in scarce supply. Each decision therefore involves consideration and abandonment of many alternative opportunities.

A second function which can be served by a long-range plan, in contrast to a short-range plan, is to influence the magnitude of the resources available to oceanography, and effectiveness of their utilization. Short-range plans, being basically extrapolations from the present, must deal primarily with the allocation of a given effort and fixed resources. On a short time scale, the overall resources to work with are already largely determined by past decisions and only minor modification is possible. Over the long run, however, decisions still to be made could very greatly affect the overall effectiveness of the effort

and lead to the development of new resources. For example, a decision to investigate the oceanic circulation directly through current measurements rather than indirectly through density determinations would have profound consequences in terms of productivity for a given budget. A reinvestment of some fraction of research funds for training and education of oceanographers expands the future capability. Some of the options which would become available to oceanography through future budgets are thus appropriate to consider in a long-range plan. Conversely, some of the presently planned opportunities which would be lost in the event of restricted growth in support can also be examined. Exploration of alternatives and their potential value can minimize undertaking or perpetuating those with less promise and undesirably high deferred costs.

A long-range plan can also take explicit account of uncertainty. Uncertainty in planning is of two kinds. The first is uncertainty which can be eliminated by one's own efforts. For example, in the question of current meter versus density investigations of the oceanic circulation there seems to be considerable uncertainty about the reliability of the buoyed meters. Also, not enough is known about the effects of other physical processes on variations in the current velocity to determine what kind of a network of observing points and intervals would be required to filter out unwanted variations and reveal those due to the process under study. What is known suggests that the velocity network would have to be much tighter than a density determination network yielding the same amount of information. Yet the density technique, although dealing with a less "noisy" spectrum than the velocity measurement technique, has the drawback that is difficult to establish absolute rather than merely relative current motion. The limitations in the usefulness of the present technique on the one hand and uncertainties about the technical and economic feasibility of the proposed technique on the other suggest that a choice between the two be postponed pending the results of an effort to remove this uncertainty. It is the function of a long-range plan to call attention to the desirability of such efforts.

The second kind of uncertainty is inherent not so much in the state-of-the-art as in the nature of the future. The outcome of the effort to establish the feasibility of direct current measurements by fixed buoys throughout the ocean cannot be predicted. Yet some of the consequence, if the effort is successful, can be foreseen. Agreements must be reached with regard to legal responsibilities and rights of the sponsoring nation; frequency allocations must be made so that radio beacons and lights do not interfere with operations of ships at sea, etc. Dealing with this kind of uncertainty requires maintaining programs which will enable uncertain or even unexpected developments to be exploited if they materialize. Similarly, if the buoyed meter technique remains either technically or logistically infeasible, such other developments as constant density floats should be supported as insurance against the failure of alternatives. Insurance is perhaps the key word in programs to be designed in the face of this type of uncertainty, insurance against both success and failure.

The goals, capabilities, and programs developed in this plan can advance the cause of other federal committees and study groups concerned with related problems. The Council's Water Research Committee, for example, is one; its Interdepartmental Committee for Atmospheric Sciences is another. The plan attempts to point out where this is the case and also acknowledges where the converse is true. Similarly, international organizations such as the Intergovernmental Oceanographic Commission and the International Hydrographic Bureau provide a framework for mutually valuable coordinated activity.

In this regard it must be realized that we are not the only nation engaged in oceanography, although we may be carrying out as much as a quarter of the total world program. This plan should therefore provide comparisons with the programs of others as a basis for estimating relative rates of progress and obtaining insights into national objectives in oceanography elsewhere.

Revisions in this plan must be contemplated as time and effort reveal the answers to matters which are now assumptions or opinions. Therefore, those with executive authority should regard it as a guide, not a blueprint, for action. They should anticipate that their decisions as well as unforeseen happenings will of necessity modify the future anticipated here, and that the new knowledge which results will provide the basis for a new plan to exploit the new opportunities to be revealed by the passage of time.

Finally, this plan calls attention to its own inadequacies and proposes measures for removing present organizational obstacles to better planning in the future.

Chapter II
NATIONAL GOALS IN OCEANOGRAPHY

THE NATIONAL GOAL IN OCEANOGRAPHY: *To comprehend the world ocean, its boundaries, its properties, and its processes, and to exploit this comprehension in the public interest, in enhancment of our security, our culture, our international posture, and our economic growth.*

SUBORDINATE GOALS: *Strengthening Basic Science*
Improving National Defense
Managing Resources in the World Ocean
Managing Resources in Domestic Waters
Protecting Life and Property; Insuring the Safety of Operations at Sea

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To show that the long-range plan in oceanography derives logically from considerations of the national interest as expressed by the abovementioned national goal is desirable, but not easy. Each of us perceives the national interest in his own way, relating it—quite properly—to his own interest. In a democracy the national interest is in fact a collective expression of regional, sectional, local, institutional, and individual interests, and as these evolve, change, and interact with each other and our environment so the national interest appears in a variable and shifting light. Nevertheless, something abides to which we all respond; the recent growth in oceanography from a ten-million-dollar enterprise involving only a few hundred professional workers in 1953 to one thirteenfold greater in 1963 pursued by a few thousand demonstrates how greatly the seas have begun to evoke this response from present-day Americans. Even if the more conservative projections of this plan apply, at least a further doubling in annual financial effort can be expected before the end of the next decade, and if some of the possibilities which are promising but as yet uncertain come to pass the amount could be far greater still.

Such figures, like the statements of public officials that oceanography is of vital importance to the Nation,* the declared intention of Congress that the United States capability in this field be second to none, and the vigorous efforts of numerous representatives of the oceanographic community such as the National Academy of Sciences Committee on Oceanography† to promote a public awareness of oceanography's scientific and social significance, are indices—though not explanations—of the extent to which oceanography is related to the national interest. For an explanation we must turn to more specific and concrete matters, the goals and responsibilities of the Federal Government.

Government is the principal agent for furthering the national interest. For this purpose it is possible to identify certain continuing goals. As stated in a recent publication by a distinguished nonpartisan group of leaders in modern American thought,‡ "The paramount goal of the United States was set long ago. It is to guard the rights of the individual, to ensure his development, and to enhance his opportunity." It may be considered that oceanography supports the maritime aspects of this goal.

In pursuit of this goal, the Federal Government has assumed a number of specific responsibilities. Those relating to defense and the general welfare for which a knowledge of the oceans is particularly pertinent are shared by some 16 agencies and bureaus within almost all the major departments of the Executive. To see why oceanography has moved nearer the center of the stage represented by the diverse activities of these departments, it is instructive to examine the missions and roles with which these agencies are collectively charged.

A. Strengthening Basic Science

The Federal Government has in recent years financed an ever-increasing share of the Nation's research and development activity. During the current fiscal year, this share is estimated at about

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*See, for example, the President's Budget Message to Congress, March 1961.

†NASCO's 1959 report "Oceanography 1960-1970" is generally considered responsible for stimulating much of the growth and interest the field is experiencing today.

‡"Goals for Americans," The Report of the President's Commission on National Goals, 1960, by the American Assembly, Columbia University.

two-thirds, where ten years ago it was less than one-half. Expenditures amount to about $12.4 billion. Ten years ago, they were less than $3 billion.

The reason for this is well understood. Science and technology have become great, if not our greatest, national resources. The discoveries of science and their applications in technology have become so woven into the fabric of modern life that "our economy, our defense, our material welfare and comfort, and our physical well-being"* would soon disintegrate and vanish without them.

Federal support for basic research has also grown—to well over $1-1/2 billion this year, roughly 70 percent of the Nation's total.

Much has been written about the need to maintain a vigorous and growing base of fundamental research, adequate to meet the suction for knowledge imposed upon it by the applied and developmental activities. Such a capability that ostensibly is free of concern for immediate use does not flourish without some measure of federal interest—and in fact, it has become a fact of history that governments become patrons of the sciences, as well as of the arts. But in contemporary terms this is not sheer altruism. We know from experience in war, in tough economic competition, and in man's fight for a life free of poverty and disability that research pays. It is the Federal Government that, in oceanography as in other fields, has strengthened basic research to provide the reservoir of intelligence needed to satisfy specific practical objectives. It must thus assume some responsibility for training and educating highly skilled manpower that it consumes, including the sponsorship of basic research undertaken by graduate students and their faculty advisors.

The scientific goals in oceanography whose pursuit is most likely to produce worthwhile scientific advances are described in the next chapter. At the federal level, the National Science Foundation and the Office of Naval Research have formal commitments to see that basic work directed primarily towards the goals of the oceanographic scientists themselves is adequately supported. Large programs in the universities and various private laboratories and institutions, including those of industry, are supported by these agencies. But in addition, other agencies have found it necessary to support some basic research as well as applied in their own agencies or laboratories. The funds from all federal agencies which are directly applicable to the conduct of basic oceanographic science in 1963 amount to about 43 percent of the entire budget, making this goal of approximately equal importance to that of defense. During the next ten years, this figure is expected to rise to 57 percent.†

B. Improving National Defense

It has become widely accepted that we, like the other major nations of the world, have a heavy stake in the preservation of peace. In the current world situation, military strength is a necessary element in our way of life. This must be a national capability so strong that the fact of its availability to the Free World is a deterrent to major infractions of the peace of the cold war.

Within our defense team the Navy's domain is the world ocean, from its deepest depths through the air-sea interface and into skies above. During peacetime one of its most important missions is maintaining the freedom of the seas so that we and the other nations of the world may enjoy the advantages of water-borne commerce and transportation so vital to our growing economy. During wartime it must, in addition, deny this freedom to the enemy.

Freedom of the seas is a phrase and a concept which, through long usage, has been taken for granted and has, for many, come to have the inevitability of a law of nature. It should be remembered that it is instead a term for a situation which in the last analysis depends on the willingness and ability of those nations dedicated to it to resist the encroachments of those who would deny it to them. The United States Navy is the major Free World force upon which this freedom now depends. Since we are without question being faced by a serious challenge to our mastery of the oceans, the Navy is energetically pursuing a multitude of significant research and development programs to maintain our dominant posture at sea.

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*"A Great Age for Science," by Warren Weaver, in *Goals for Americans*, The American Assembly, Columbia Univ., 1960.

† Funds for conduct of basic research include costs for ship operations, instruments, and expendable supplies.

In oceanography the major objective, of course, is the greater understanding of the environment to enhance our capabilities in all forms of warfare. One example, and perhaps the one which most directly benefits from oceanography, is Anti-Submarine Warfare. Here, the sophistication and effectiveness of major improvements which have been made in weapons systems have been due not only to increased knowledge of the environment, but largely to advances in other areas of science and technology. Signal processing is a good example. The effective utilization of these systems, however, requires a broader and more detailed understanding of the environment, its properties and processes. Such understanding will, in addition, lead to new concepts of operations as well as new systems. It is for this main purpose that the Navy has undertaken a major oceanographic effort.

Let us briefly examine some of the properties of the environment and manner in which they influence naval planning. Sound is the only form of energy which propagates to any distance in the sea so that this work centers on audibility problems. A submarine's audibility to underwater listening gear in various operating areas during the different seasons of the year depends not only on sound transmission conditions, which are affected by the temperature, salinity structure, depth, and reflectivity characteristics of the bottom, but also by the screening effect of noise created by breaking waves at the surface, the engines of other marine traffic, and the creaks, groans, snappings, and whistles emitted by a variety of sea creatures.

This is as true, of course, for enemy submarines as it is for our own. Everything we learn about how to hide our Polaris boats from enemy detection contributes, therefore, to our knowledge of how best to go about finding his.

When it is realized that sound not only travels five times as fast in water as it does in air but for a given source intensity produces pressures which are some 60 times as great, it is not surprising that such ordinary sounds as the singing of rotating propellers and the swish of bubbles and eddies in the passage of a hull through the sea, all of which seem of comparatively short range to a listener on land, suddenly assume tremendous significance when the sound source is in water and the listener has "underwater ears."

Furthermore, the ocean is layered to an extent seldom realized in the atmosphere and the transmission of sound by "channels" in a fashion somewhat like the production of mirages in the air is a common occurrence in the sea. Submarines tens and even hundreds of miles away can sometimes be heard by listening equipment exploiting these sound conduits. Some layers, the most persistent, are very deep and can be utilized only by hydrophone arrays lowered down the sloping edges of islands or on the edges of the continental shelves to catch the deep sound transmission. Certain frequencies in the sound spectrum are more favored than others under some conditions. In general, the high frequencies are more easily attenuated and it is the very low frequencies which travel farthest. Since the size of the underwater ear must match the size of the wavelength being listened to, there is a complex design problem involved in fitting equipment to specific operational missions. That is, there is an important difference in systems optimally suited to an acoustic environment where treble notes with wavelengths of a few inches dominate as compared to systems best suited to one where the bass notes which have wavelengths of many feet are most important.

The essential point is that increasing the range of detection of hostile submarines and the accuracy of target classification depends critically on oceanographic research. The Navy's Oceanographic Office, the Bureau of Ships, and the Office of Naval Research conduct or support research on various aspects of this problem, including the prediction of the key features of the "anti-submarine warfare environment" and how to exploit it operationally.

Almost every other Navy mission depends on similarly complex and critical relations between operations, technology, and environment. One reason aircraft carriers must be so large, for example, is to be sufficiently stable in a seaway that high-performance aircraft need not be exposed to dangerously large excursions of the flight deck as they approach the stern for a landing. Even high-speed destroyers and frigates have to slow down if waves are too high, and faster transits to distant operating areas can often be made by taking "the long way around" and avoiding the worst sea conditions enroute. Where timely arrival on the scene is important, such routing could spell the difference between failure and success. Weapons technology is also pressing against

environmental constraints as torpedoes, missiles, and bombs have to push their way long distances at high speeds through the water or penetrate the interface between the sea and air without undue interference from waves, to find their optimal depth for detonation.

"Habitability" in the deep sea environment into which future submarines are expected to penetrate must be studied before the various compromises between size, structural strength, performance, and expense can be made intelligently. The ability of divers to work underwater with varying degrees of mechanical assistance is also of interest. The Bureau of Weapons and the Bureau of Medicine have important oceanographic programs in these areas.

The Navy's concern with these and many other facets of the ocean environment is reflected within its oceanographic budget. In Fiscal Year 1963, the Navy effort accounts for about 44 percent of the federal funding—$57 million of a total of $123 million. In addition to this work, the results of which may be applicable to many nonmilitary problems, the Navy allocates a substantial additional amount ($26 million in FY 1963) to projects which are classified or which are of a more direct and unique military nature. These latter projects are not included within the scope of the program embraced by this report but are detailed in TENOC—the Navy's comprehensive Ten-Year Plan in Oceanography.

Over the ten-year (1963-1972) period of this long-range plan, the Navy total is expected to be about $835 million, about 36 percent of the whole. Military oceanography not included in the plan amounts to $480 million additional.

These fiscal requirements would be greater still if interagency cooperation did not exist to make available to the Navy, information about planning of research on biological phenomenon by the Bureau of Commercial Fisheries and the Smithsonian Institution, and on the characteristics of the ocean bottom of importance to ASW, Mine, and Amphibious Warfare, by the Coast and Geodetic Survey and the Geological Survey. The Army Corps of Engineers also contributes much information on harbor and channel regions in support of navigation and Mine Warfare operations, and the Atomic Energy Commission cooperates with all three services in atomic tests where underwater sound propagation, wave propagation, shock effects, contaminant dispersal, and cratering can all be studied.

It is implicit that while various agencies contribute to defense oceanography the converse also occurs. As we have already seen, this is particularly true of programs sponsored by the Office of Naval Research. It is also true of the work of the Oceanographic Office. Nearly one-third of the Navy's oceanographic budget is devoted to supporting research in universities and private laboratories. Thus, the Navy's support of basic and applied research, amounting to about 22 percent of the entire national oceanographic budget in 1963 and nearly 20 percent over the coming decade, does a very important double duty. It supports the national defense effort, but simultaneously it strengthens basic science upon which progress in oceanography so greatly depends.

Earlier, it was noted that the Navy's primary motivation for oceanography was related to its position as a member of the defense team of our Nation, and within this team, to maintain the freedom of the seas. As the remainder of the National Plan and its goals are described, it would be well to remember that the pursuit of oceanography toward each of these other goals is dependent on this freedom of the seas which the Navy provides, and which the Navy's oceanographic program sustains.

C. Managing Resources in the World Ocean

The tyranny of nature is still the tyranny of most consequence to people throughout much of the world, and for these people the freedom of greatest immediate interest is the freedom from want. The two aspects of freedom, freedom from the tyranny of nature and freedom from the tyranny of thoughtless or malevolent men, meet in the world's oceans where the largely unregulated activities of men promise increasingly to create problems of world health, of the safety of operations, and of the ownership and use of important resources one of which, food, could relieve the cruel grip of hunger now confronting so many of the world's people.

Estimates of this potential are easy to arrive at but difficult to justify. The present world fish catch is estimated at about 40 million metric tons, or a bit over 88 billion pounds. World protein consumption now totals something like 400 million metric tons, so that if everyone's diet were the

same the present fish catch would supply 10 percent of the protein needs of the world's population. In fact, it may supply more, being more highly favored by those with lower standards of living whose per capita protein intake is less than average. An estimate generally accepted as conservative puts the annual catch which could be sustained indefinitely without depleting the stock at something like 200 million metric tons of fish a year, or about five times the present take. More optimistic estimates range to many times this value. All agree, however, that vastly more information must be obtained on the ecology of fish populations and their distribution than is now available and that much more efficient management techniques must be developed and international agreements reached if even the lowest of these estimates of the potential food harvest of the oceans is to be realized.

The motive for making the necessary effort soon gains much of its strength from two considerations. One is that many of the fish presently most valued are already showing signs of overfishing, and the other is that the major alternative, intensified agriculture, seems promising mainly in land areas of rich nations while many starving nations border the seas which, in principle at least, are accessible to all.

The United States is a member of eight active international fisheries commissions in which a total of 20 other countries also participate. These commissions and their dates of establishment are: Pacific halibut, 1924; Pacific salmon, 1937; international whaling, 1948; inter-american tropical tuna, 1949; Northwest Atlantic fisheries, 1949; international North Pacific fisheries, 1952; Great Lake fisheries, 1955; North Pacific fur seal, 1957. As world fishing develops, the catch seems to be doubling every 12 years. More fisheries are becoming mature and require close supervision. Under consideration for control are the yellowfin tuna of the eastern tropical Pacific and certain other fishery stocks. Both for the economic benefit of the fishermen who see their livelihoods at risk and for the benefit of the populations who need what the seas can offer, learning how to find and exploit alternate species as well as how to increase the safe yield from present species is of vital importance.

The Bureau of Commercial Fisheries is tentatively planning to spend approximately $173 million over the next 10 years on programs which will contribute directly to better management of fish resources in the sea. Although approximately $69 million of this is to be devoted to the study of species which are now entirely or predominantly the province of the American fisherman, even those are bound up in the broad ecology of the oceans of which man is becoming the chief predator and for which he must be prepared to be accountable as competition for the food resources in the world ocean stiffens. Another $185 million will go to basic research, strengthening oceanographic science while laying a much needed foundation for more effective applied work on fish resources management. This is in acknowledgment of the importance of knowledge of ocean circulation and vertical transport to prediction of the distribution of fish populations and general oceanic ecology.

The Smithsonian Institution plans to spend about $25 million over the decade in describing organisms—their abundance, their life cycles, and their distribution in the ocean. The Smithsonian effort will contribute significantly to our understanding of both beneficial and harmful biological processes in the ocean. Although the Smithsonian may charter vessels for brief periods of time for work in remote areas, most of its collecting will be performed on ocean-going vessels of other agencies.

The health of the fish and other life which inhabit the ocean may be affected by poisons introduced by man in various ways; man himself may then be affected when he consumes contaminated seafood. He may also be affected by these poisons directly. Since the testing of nuclear weapons began after the war, the people of the already uneasy world have become increasingly concerned about the radioactive contamination of their environment. Disposal of low-level radioactive wastes by AEC in both the Atlantic and the Pacific Oceans since 1946, and by the British in the Irish Sea, has made it necessary to study ultimate consequences as the packages in which they are contained corrode through over the years and even the sluggish circulation in the ocean abysses eventually disperses them widely over the world. Nuclear reactors power a large number of submarines and an increasing number of surface ships, and are being developed to provide both electric power and propulsion for satellites and space vehicles. Appraisal of operational and accidental hazards that these devices represent

requires similar study to reinforce public confidence in the safety of such operations.

The Atomic Energy Commission plans not only to expand its already extensive monitoring efforts at test sites, in the vicinity of stationary reactor sites on land, and at the places where wastes are disposed of at sea, but also plans greatly to expand its research effort on the effect of nuclides in ocean water in general. It expects to spend about $68 million over the decade and will be assisted by the Navy, the Coast Guard, the Bureau of Commercial Fisheries, and the Public Health Service in one or another aspect of its work. Nearly half of these funds will go to support basic research. During the period of this report, our efforts at inventorying and understanding the biological wealth of the world ocean will account for 19 percent of the total budget; over half of this will be spent for basic research. A portion of this work has implications primarily for the U.S. public, as discussed in the next section.

D. Managing Resources in Domestic Waters

1. SAFEGUARDING PUBLIC HEALTH

The streams and rivers into which man pours his industrial waste and sewage in increasing concentrations as they flow through the countryside eventually reach the broad estuaries where they slowly mix with the sea. Although water, both fresh and salt, contains numerous chemicals and organisms capable of reducing noxious substances to harmless ones, and although dilution itself is of tremendous value, local concentrations of dangerous toxicity have always been a potential hazard, the vagaries of currents and flow being what they are. The ability of some organisms used for food by man to tolerate and store poisons at levels of concentration serious or even lethal to man is well-known. Shellfish are particularly important, being susceptible as well to toxic substances not produced by man. Oceanographic studies concerned with the effects on estuarine and inshore waters from the disposal of municipal and industrial wastes have been conducted for years by the Public Health Service and the Bureau of Commercial Fisheries, and where they concern inshore marine foods this work is done in close cooperation with the states.

These traditional programs have recently assumed much greater importance due to the vast increase of population, and the consequent rising concentrations of "normal" wastes in our streams and estuaries, and to the appearance of new and highly resistant chemical wastes produced by modern technology. Radioactive wastes discharged by atomic plants are the first of the new long-lived poisons which come to mind, but many other less familiar chemical products may be even more hazardous. Among these are alkylbenzene sulfonates (ABS), DDT, Aldrin, Parathion, Lindane, and a variety of nitrogen compounds. As a consequence, not only has the Atomic Energy Commission undertaken an increasing program in oceanographic research but the programs of the agencies traditionally concerned with oceanography have also expanded their research in marine pollution.

In 1963, the goal of safeguarding health in relation to seaside pollution accounted for about four percent of our oceanographic budget. Over the decade ahead it is likely to remain about the same, totaling about $95 million.

2. CONSERVATION OF RESOURCES HELD IN COMMON

In 1947, the Supreme Court decided that the Federal Government and not the State of California had title to the submerged lands off the coasts of the United States. This decision and the two that quickly followed against Louisiana and Texas ended the uncertainty over rights which had hampered the oil industry in its efforts to exploit these areas.

Since then the oil companies have invested approximately $3.5 billion in exploratory drillings along the continental shelves. Oil reserves offshore are far from being estimated. Their studies have largely been confined to areas of probable oil occurrence.

The mineral resources of the sea come next to mind. Although the sea contains dissolved minerals in nearly astronomical quantities, their dilution is so extreme that extraction is both difficult and expensive. Furthermore, most can be found in adequate amounts and with sufficient ease on land. Consequently, with the exception of a few minerals such as bromine and magnesium, neither industry nor the Federal Government has taken much interest in developing oceanic sources. Now, however, the picture is beginning to change. Large deposits of nodules rich in manganese, nickel, and cobalt, which were stumbled across

on the ocean bottom many years ago, and some minerals extractable from sea water have assumed more importance.

The Bureau of Mines now intends to initiate both a comprehensive research program on the extraction of dissolved chemicals and a program to develop and explore sources on and beneath the ocean floor. This program of exploration, to begin most logically with the continental shelves (and the Great Lakes) where the water is only a few hundred feet deep and the geology similar to that of the continents, summons up thoughts of such past expeditions into the unknown, or only partly known, as the Lewis and Clark Expedition. Although much can be done by sampling and surveying from specially equipped surface vessels, when the few tens of miles of the shallow continental shelves are left behind for the vast abyssal plains where the water is two or three miles deep and the geology is unlike that ever before seen, efficient exploration will necessitate man's actually getting down and looking around. The Bureau of Mines is, therefore, considering the development of a manned deep submersible to supplement its other exploratory techniques. This submersible is to be shared with the Bureau of Commercial Fisheries and possibly other agencies. The landscapes seen for the first time by these underwater explorers can hardly help but produce strange and perhaps awesome experiences.

The Geological Survey will also participate in developing information on and maps of mineral resources.

Another resource which will always be held in common is the recreational value of the sea. Sport fishing and boating have been the traditional forms of recreation at sea just as the beach areas have been for swimming. To these traditional forms of ocean or oceanside recreation, SCUBA diving and underwater exploration in small submersibles and motorized underwater scooters have recently been added or are in prospect. As yet, it is not clear what needs to be done not already in hand by the various federal agencies long active on behalf of seagoing or seaside recreation. As is well-known, the Bureau of Sport Fisheries and Wildlife is engaged in game fish research; the Geological Survey, the Beach Erosion Board, and the Coast and Geodetic Survey provide data and studies for the use of oceanside recreation industries; and the National Park Service, which has lately become interested in underwater parks and nature trails for skindivers, maintains and operates public beaches and recreation areas while the Coast Guard and the Weather Bureau provide storm warning and rescue services.

Cultural patterns in the U.S. will continue to change with the rapid growth expected in the recreational industry. Private developments will be watched for indications of the need for future government activities on their behalf and on behalf of the conservation of resources themselves.

In 1963, about two percent of the oceanographic budget was considered to support this goal. This factor should double in the decade ahead.

E. Protecting Life and Property Ashore; Insuring the Safety of Operations at Sea

1. PROTECTING LIFE AND PROPERTY ASHORE

Those living near a seacoast are all too well aware of the hazard to life and property represented by a storm at sea. Hurricanes are most likely in late summer and early fall, but extratropical storms may strike our Atlantic and Gulf Coasts at any season, sometimes with immense damage. Although the high winds associated with these storms can sometimes do great and freakish damage, it is the water which is the greatest threat. Tides sometimes run many feet higher than normal as so-called "storm surges" associated with the storm moving along the coast. Huge waves whipped up by the wind slam into shore, imposing forces measured in the thousands of tons against beaches, piers, and breakwaters with all the impact of a sequence of freight trains.

Both prediction and protection are important for dealing with these hazards. The Army Corps of Engineers through its Beach Erosion Board, conducts studies on the numerous factors which influence the way and amount waves and currents affect the coasts, including the modification of these effects by protective installations. The Weather Bureau not only attempts constantly to improve its ability to locate and predict the movement of such storms but also to predict more accurately the seas that they generate. That this last problem is difficult and only partially solved can be appreciated when it is realized that wind-generated waves run constantly away from the

areas of generation at rates sometimes faster than the wind speeds by which they are produced, and much faster than the rate of progress of the storm centers that cause them. Also, the effectiveness of the wind in producing waves depends on what it has to work with; that is, over what reach, and how high the sea is already. The consequence is that the sea at any particular point in time and space is the joint product of many, many storms, some of them hundreds or perhaps thousands of miles distant, some interacting with others in the regions of wave generation and all being felt to some extent at the point of observation. Finally, as the bottom shoals toward land, its contours and their orientation modify the waves which roll in from the open sea, often augmenting their already formidable aspect.

The importance of the atmosphere-ocean interaction to prediction problems such as the genesis and life history of tropical storms is widely recognized. To increase the accuracy of short-range and long-range weather predictions oceanographic parameters are being considered and feed-back processes taken into account. Part of the energy which drives ocean currents and generates the waves at the sea surface is derived from the winds; another part of the energy is transmitted to the ocean by radiational processes which are modified by atmospheric conditions. But the winds and atmospheric conditions themselves depend on the distribution of physical properties in the ocean. Therefore, oceanic circulation and atmospheric circulation are closely linked and are being studied by the Weather Bureau to provide ultimately a better service to the public.

Research programs of the Army's Beach Erosion Board and the Weather Bureau for prediction and protection in relation to coastal areas are expected to total about $16 million and $1 million respectively over the decade.

Another deadly threat to life and property along the same seacoast, because it strikes without noticeable warning, is the seismic sea wave or tsunami, long an object of study and concern to the Japanese who have given it its name. Earth shocks, resulting in sea bottom movement, particularly frequent in the volcano-ringed Pacific, start water waves traveling out from a point at the surface above the center of the disturbance with speeds of 400 or 500 miles per hour. Ocean wave speeds are partly determined by wave length. Tsunami wave lengths, due to the method by which they receive their initial energy, are many hundreds of times greater than those produced by even the most violent wind. These very long waves "feel the bottom" even over the deep ocean abyss in much the same way the shorter wind-created waves start to feel the bottom as they reach shoal water along a beach, and the effect produced is the same, though magnified immensely by the proportionately greater change in depth. The upper portions of the wave begin to override the lower parts, and what would be an almost unnoticeable rise of a foot or two in the open ocean becomes a rise of perhaps 50 feet against a coastline across its path. And since these waves carry thousands of miles from the point of origin, they arrive unaccompanied by any other phenomenon which might announce the impending disaster.

The series of waves which struck the Hawaiian Islands on April 1, 1946, destroyed 173 lives and $25 million worth of property. It led to the establishment of the Seismic Sea Warning System by the Coast and Geodetic Survey, which already had a network of tide gauges in strategic locations around much of the source region. By extending the network, tying it into the network of seismological stations, and adding accurate time devices and instant communications, the Coast and Geodetic Survey is now able to predict with high accuracy the time of arrival of such waves at Hawaii and elsewhere in the Pacific and to issue warnings well in advance.

That the system is not perfect, however, is witnessed by the most recent tsunami which hit the city of Hilo in May 1960, destroying 61 lives and about $23.5 million in property. A major defect in the system is its inability to predict the amplitude of the wave, and many apparent false alarms result when the tsunami is so small that it arrives unnoticed by the residents. By the same token, it is impossible for a resident to distinguish a warning which may be followed by an unusually dangerous wave. The same tsunami, produced by an earthquake off the coast of Chile, showed another major defect of the system. It presently provides warning for only a few other areas of the Pacific which may be as badly threatened as Hawaii. The shores of California, Alaska, Japan, and many other areas were all greatly affected and widespread loss of life and property occurred. Much more research on the phenomenon is needed, and the warning system improved and extended.

Since the problem is international, it is necessary that the solution to it will be also.

Less spectacular but nevertheless of importance are the ravages of marine organisms on man-made structures. For example, it is estimated that about $250 million is spent annually for maintenance and repair of damage caused by marine organisms. Oceanographic work sponsored or conducted by the Navy's Bureau of Yards and Docks, the Office of Naval Research, the Maritime Administration, and the Atomic Energy Commission all has a bearing on this problem.

2. SAFETY AT SEA

Closely related to protecting life and property along the coasts is the responsibility to help assure the safety of operations at sea. It is shared by the Coast Guard, the Navy, the Coast and Geodetic Survey, and the Weather Bureau. For example, the annual spring "calving" of glaciers into hazardous floating icebergs and cakes of many sizes is monitored and warnings to shipping issued by the Coast Guard's conduct of the International Ice Patrol. Theoretical studies to support better prediction of likely courses taken by sea-ice and how long it can be expected to take to melt are also important. Weather Bureau and Navy weather predictions at sea are invaluable to shipping, and Coast and Geodetic Survey and Navy Oceanographic Office charts of navigational hazards and aids are being constantly improved and updated from survey work. As submarines go deeper, detailed bottom mapping will assume even greater importance as will determining the location of sea mounts and underwater mountain ranges rising toward the surface.

With the advent of meteorological satellites, their potential in oceanography must be explored. There are already indications that they will be useful in surveys of sea-surface temperatures and radiation (heat budget of the ocean), ice reconnaissance and sea-state observations. Such information will help greatly in oceanographic forecasts. It is expected that at the end of the ten-year period the Weather Bureau will be making a substantial effort in helping to solve these problems.

Most of the protective effort against natural hazards is operational or engineering, so that the small funding for oceanography under this goal (about two percent of the ten-year oceanographic budget) is only a small part of the story.

F. Summary

To comprehend the world ocean, its boundaries, its properties, and its processes, and to exploit this comprehension in the public interest, in enhancement of our security, our culture, our international posture, and our economic growth involves:

Strengthening Basic Science
Improving National Defense
Managing Resources in the World Ocean
Managing Resources in Domestic Waters
Protecting Life and Property; Insuring the Safety of Operations at Sea

These are the national goals toward which the federally supported oceanographic program is directed. They are more easily separated in concept than in practice. Each leans on one or more of the others for its own fulfillment and work done with the intent of furthering one may in the end more materially benefit another. Nevertheless, they are useful concepts, and particularly so when a framework is needed for organizing a plan such as this, a framework in which emphasis and balance can be more clearly seen.

The budget required for oceanographic programs, ships, instruments, and facilities to meet the aggregate national goals, taking into account availability of skilled manpower, should grow an average of 10 percent to 11 percent a year from a level of $124 million in FY 1963 to $350 million in FY 1972, for a total of about $2.3 billion over the decade. Over 44 percent of the federal budget will go to private laboratories as compared to 37 percent in 1963. The total ten year budget is allocated among the various goals as follows (Further delineation is provided by Table 1):

1. About 57 percent will support basic research and serve to strengthen basic science; 33 of this 57 percent will contribute simultaneously to scientific development for other national goals as shown below. In 1963 this figure was nearer 43 percent.

2. About 35 percent will support defense as compared to 44 percent in 1963. Some 20 percent supports Navy basic research already included in (1) above and 15 percent supports applied programs.

3. Some 19 percent of the effort will go to improve our ability to manage resources and control threats to health in the "world ocean" (11 percent basic included in (1) above, and 8 percent applied). Only 15 percent of the 1963 budget can be considered to serve this purpose.

4. About 8 percent will go to discover and exploit resources on and under the continental shelves and to protect the health of the U. S. public from coastal pollution and other poisons (two percent basic included in (1) above and six percent applied). In 1963 this figure is about six percent.

5. Less than two percent will be applied to protection of lives and property ashore and safety at sea.

6. About 12 percent will provide oceanographic services such as nonmilitary ocean surveys, data processing and archiving, and instrumentation calibration and standardization which benefit all members of the oceanographic community. This is a drop from the 20 percent figure in 1963.

Although much can happen to modify these projections, as is explained in Chapter IV, these represent the desired balance of effort weighing need against manpower available and against opportunities as viewed by the federal oceanographic community at the present time. In brief, emphasis in this National Plan is to be placed on private laboratories and universities, and on basic research, with exploitation for peaceful uses becoming increasingly a more prominent objective.

Chapter III
SPECIAL GROUPS CONCERNED WITH OCEANOGRAPHY

One of the fundamental goals of the Federal Government is "to ensure the development (of the individual) and to enhance his opportunity." There are several private seagoing groups whose development and opportunity can be considerably enhanced by oceanographic knowledge. Among these are the fishing industry, the shipping industry, the oil and mining industries, the ocean-related sport industries, and the community of oceanographic scientists itself. To the extent that it is compatible with broader national goals, the Federal Government should conduct its oceanographic program so that it supports the goals of these special groups as well. To see how this can best be done, let us next examine these individual goals as they involve oceanography.

A. Oceanographic Science

It has already been argued that there is an identity between the federal goal of strengthening oceanographic science and the scientist's goals in pursuing oceanographic knowledge for its own sake. Of course, it must be added that this identity is one of kind and not of degree. Some reasonable portion of the scientist's time and effort must be directed toward the numerous other and more practical goals of the government which is sponsoring his work. As an oceanographic scientist, however, what is it that interests him?

In oceanography, the National Academy of Sciences, through its Committee on Oceanography (NASCO), speaks for the scientific community as much as any committee can speak for people who are traditionally accustomed to speaking for themselves. The particular front-lines in oceanography as they existed four years ago which were singled out for special mention in NASCO's report of that year* are typified by a few of the questions posed in Volume II of this report, "Basic Research in Oceanography during the Next Ten Years." These fall into five main areas:

1.THE HISTORY OF THE OCEANS

"Why is the layer of unconsolidated sediments in the deep sea so thin, on the average only about 300 meters in thickness?. . . Why do we find fossils of Tertiary or Cretaceous age but none older? (That is, under about 100 million years.)

"In most cores taken in the Pacific and Atlantic there seems to be a sudden increase in radium content at an age level of about 200,000 years. What is the cause of this increase? . . .

"What is the history of the deep, narrow, almost sediment-free trenches that ring the Pacific Basin? . . . Why are these border features . . . apparently the loci of very low heat flow from the earth's interior?

"Existing abyssal plains are all adjusted to recent topography. Where are the ancient abyssal plains? . . .

"How have the broad swelling ridges that bisect the Atlantic and the South Pacific been formed? How old are they? Why are they the loci of very high heat flow from the earth's interior?

"Faults around the margins of the Pacific Basin appear to be right lateral as though the basin were rotating counterclockwise. Does submarine topography support this hypothesis? Are fracture zones the spokes of the wheel?

"Is the base of the crust a phase transition, or is there a real difference in chemical composition between crust and mantle?

"Are there pools or sheets of molten rock deep beneath the earth's crust associated with inland arcs, trenches and fracture zones? . . .

"What are the reasons for the large scale, remarkably regular magnetic topography of the deep sea floor off the west coast of North America? . . .

"What is the history of sea water? . . .

"How did the pattern of the major ocean currents during past times compare with that of today? . . ."

2. THE WAYS OF LIFE IN THE SEA

"The fauna and bacterial flora of the great deeps provide unique opportunities for the general biologist. Nowhere else can he find organisms adapted

*Oceanography 1960-1970, a Report of the National Academy of Sciences Committee on Oceanography, 1959.

to such high pressures and perpetual low temperatures. It also offers him intriguing questions:

"What are the enzyme systems that operate in these conditions?...

"What is the meaning—the function and history—of those strange structures, 'fishing rods' and 'lanterns', that characterize known inhabitants of the deeps?...

"Did an original ancient fauna adapt to and survive the severe drop from 12° to 2°C; or did this change bring widespread extinction and replacement?

"Recent years have brought discoveries of extremely ancient organisms;

"Under what conditions have these 'living fossils' survived? How can we account for the radically different evolutionary rates that we find in the sea?...

"The plankton is formed typically of small essentially floating creatures that we might expect to be uniformly dispersed, hence evenly distributed...

"How does the plankton, apparently helpless in the face of water movement, maintain discrete distributions?...

"What factors limit the distribution of communities, regulate their abundance and determine their internal structure?"

3. THE MOTION OF THE WATERS

"Direct current measurements during the past year have shown that the east-west transport of water in the eastern tropical Pacific is probably at least three times that previously estimated. We may ask:

"How good are some of the other estimates of water transport? Just what, how big, and how complex is the circulation pattern of the oceans? This question leads in turn to others. What are the 'time constants' of the oceans? Why are some water masses but not others homogeneous over hundreds of thousands of square miles? Why is there the vast oxygen minimum beneath the thermocline in the tropical eastern Pacific and eastern Pacific and eastern Atlantic? What is the rate of mass exchange across the thermocline? Even more fundamentally, how are thermoclines formed and why do they persist?

"That the questions listed above remain unanswered reflects not only the lack of quantitative measurements of the motions of the ocean waters, but also the inadequacy of our thermodynamic and hydrodynamic models of the sea and the air. The two great earth fluids can be thought of as interlinked heat engines, and both theory and experiment need to be concentrated on the boundary between them...

"How are the waves formed, and how do they grow and decay? What is the partition of energy and momentum, transmitted by the wind to the sea, between waves, currents and turbulent motion?

"Waves beneath the sea surface, called internal waves, are far more mysterious than the waves at the surface.

"How are internal waves generated? Do they break near shore? Are they effective in mixing nearshore water? What is the role of internal waves of tidal period in tidal friction?"

4. OCEAN-ATMOSPHERE RELATIONSHIPS

"So intimately connected are the oceans and the atmosphere that basic research in one field must necessarily involve the other...Studies of these relationships may be highly fruitful in long-range weather forecasting.

"Less well-known and little understood are the long-term effects on climate caused by the ultimate stirring up of the deep ocean waters.

"Does the supply and coldness of the deep water vary at its source around Antarctica from year to year, or decade to decade? And if such variations occur, how long after and by what mechanism do they affect climate?

"In the deep waters of the sea, with their slow transport, we have a natural built-in lag which is a most promising beginning for the understanding and ultimate prediction of long-term climatic fluctuations."

5. ESTUARIES AND COASTAL WATERS

"Men have lived since time immemorial near the seashore and have benefited from the natural resources of inshore waters. Yet little is known about basic processes at the margins of the sea. Consequently, coastal and estuarine waters are now claiming an increased share of attention from oceanographers.

"Some of the questions are:

"What are the mechanisms of sediment erosion, transportation, and deposition on the shelf and in the surf zone?...

"How are turbidity currents generated? Are they the primary means of transporting terrestrial material to deep water? At what speeds do they flow?...

"What is the flux of sediment from land to deep ocean?...

"What is the nature of the stress exerted by waves and currents on the bottom?...

"What world-wide changes in sea level have occurred in the past? What changes are in progress now, or are to be expected in the near future?"

In general, the same questions challenge oceanographic scientists today at just the time that technology and engineering have put the answers to many of them tantalizingly near his reach. The assessment of the National Academy of Sciences four years ago was "that both the quantity and quality of basic research in the marine sciences can and should be increased substantially during the years ahead." The challenge and promise are even greater now.

B. The Fishing Industry

The remaining groups to be discussed, such as the fishing industry, are primarily consumers of oceanographic information, though some of them, like the government, may be producers or at least patrons of it also. The questions they ask of oceanography are highly practical and the motive is largely economic. To see their oceanographic needs, we must therefore view them in an economic setting.

Commercial fishing has been an important industry on this continent for nearly three and a half centuries. Today it supplies over a million tons of food each year for our population, which consumes an average of nearly 11 pounds a year per person. More than half a million people depend on it for their livelihood.

1962 was both favorable and unfavorable to the American fishing industry. On the favorable side, the year was one of the most prosperous in American fishing history. Catches of salmon and shrimp were sharply up from 1961, and the tuna industry, although short of its all-time high, had another successful year. Even the New England groundfish industry, beset by competition from foreign imports, did reasonably well. Only the oyster industry fared badly, but research already well advanced is expected to brighten its future also.

The most unfavorable aspect is the increasing competition from the fisheries of other nations. This competition takes two forms: cheaper imports from countries with labor costs lower than ours, and the invasion of traditionally American and Canadian fishing grounds by foreign fleets, most notably those of the USSR and Japan.

Technological problems arise from the advanced age of many of our fishing vessels, lagging progress in seafood processing, and from the adverse effects on some seafood stocks of pollution and engineering projects as well as from environmental changes due to natural causes. Technological progress is being made, however, in some quarters. Among these are the use of power blocks and synthetic fiber nets in the salmon and tuna fisheries and the widespread adoption of automatic peeling and shucking machines in the shrimp and crab industry. The industry has also recognized the advantage of voluntary quality inspection of many fishery products.

There is a strong feeling that one of the most promising avenues for the future is further development of fish protein concentrate. This material, a flour-like substance, can be made cheaply from fish wastes and from species either not being caught at present or now being discarded as trash. It is stable, easily transported and stored, and has a very high protein content. These characteristics make it particularly promising for use by countries with poor distribution and transportation systems, among which are many with diets seriously protein deficient.

A necessary condition for successful competition with foreign fleets is superior knowledge of the sea and its inhabitants. With some important exceptions, the industry is largely dependent on the Bureau of Commercial Fisheries for this knowledge. Since many areas of potential interest are remote from U.S. shores, international cooperation is frequently essential. The two large-scale international enterprises in which this country is now participating, the International Indian Ocean Expedition and the International Cooperative Investigations of the Tropical Atlantic, represent important steps toward a better understanding of these two areas of potential interest to American fishermen.

The industry feels that knowledge is not enough, however. It needs more capable ocean-going fishing vessels, and more modern and efficient techniques for locating and capturing the fish.

It will probably need federal assistance in developing, building, and operating such improved gear. It especially needs intervention by the Federal Government in developing international agreements on fisheries management. For as the inevitable increase in take occurs, whether or not Americans help produce it, the problems of rational exploitation discussed in the previous chapter will become critical. The scientific knowledge needed to further this national goal by effective participation in international regulatory bodies is critical for the fisheries whose livelihood is at stake.

C. Offshore Oil Industry

Offshore oil production in the United States began in the Gulf of Mexico from the Creole field adjacent to the Louisiana shoreline in 1938. It was followed by somewhat slower development off the California and Texas coasts.

Today there are also oil and gas fields producing in many inland bodies of water throughout the world, such as in Lake Erie. The largest offshore oilfield in marine waters is in the Persian Gulf, off the coasts of Saudi Arabia and the nearby Neutral Zone. Other producing fields are in the Gulf of Suez, off the shores of Venezuela, Japan, Mexico, Trinidad, and Peru. Operations are expected to be extended both geographically and in depth.

The magnitude of the offshore operations is illustrated by figures for the Louisiana marine area. Total investment at the end of 1962 exceeded $3 billion, with a forecast of $2.6 billion to be invested in the next five years. From 1938 to July 1, 1962, a total of 4325 wells had been drilled. Liquid hydrocarbon proved reserves exceed 2 billion barrels, plus 12 trillion cubic feet of natural gas reserves. In the essentially unexplored water depths of 100 to 600 feet, some 250 new oil and gas fields are expected to be found eventually. As many more fields may be found in shallower waters in the Louisiana area.

Oil production in this area, beyond the three-mile limit, has increased steadily from 3 million barrels in 1954, to 11 million in 1956, 36 million in 1959, and almost 88 million barrels in 1962. Offshore natural gas production has had a similar growth, with cumulative sales for all offshore Louisiana now 2 trillion cubic feet.

Project Mohole (not fiscally included in the National Oceanographic Program), a plan to drill through the earth's crust into the mantle, has demonstrated in the first phase of operations that drilling can be done in water as deep as 12,000 feet, and subsequent phases should enhance offshore drilling technology. An industry drilling vessel is now operating in 277 feet of water 40 miles from the Louisiana shore. This equipment is designed for use in waters 600 feet deep.

Cost is the major problem of the oil and gas industry in offshore operations. Equipment investment costs obviously are much greater than for onshore exploration, drilling, and production. Drilling and operating costs for a 10,000-foot well are about 50 percent more offshore than onshore. However, offshore drilling to date has been more productive (about 4 to 1) in terms of reserves found.

The oil industry has been relatively self-reliant in its oceanography and underwater geology. Information in its files on the topography and structure of many areas along the continental shelf probably exceeds that available elsewhere in both scientific quality and quantity. The beneficial effect of permanent structures and islands at sea on fishing is well-known. These structures attract fish and provide a desirable environment for them. This in turn attracts fishermen. Underwater television cameras used by the industry already have photographed forms of sea life not known before. Technically, many of the innovations developed in the search for oil under the seas have been immediately useful to other industries and other scientific pursuits. Much geological data, now unavailable for proprietary reasons, would also be of great general value if the oil industry finds itself in a position to release it in the future. Exploration of marine areas by the oil industry has been largely confined to areas of considerable economic potential, as for example, along the Gulf Coast and the coast of California where producing fields and geologic conditions of promise extend seaward. As on land, the industry looks to government for exploration in areas of unknown or marginal oil and gas potential.

D. The Sea-Mining Industry

Diamonds are recovered along the coast of South Africa, tin is dredged from shallow waters off the

Indonesian archipelago, Japan mines iron from its coastal waters, and heavy minerals are taken from beaches and near beach areas of the United States, Australia, and India. Sulfur is recovered from beneath the Gulf of Mexico. Coal has been mined from tunnels extending from land to points under the seas in Canada and England, and bromine, magnesium, iodine, and common salt are recovered commercially from sea water.

However, all present marine mining is in relatively shallow waters less than 400 feet in depth, and the equipment employed is generally the conventional hydraulic or bucket dredge. Normal evaporation, chemical precipitation, and ion-exchange procedures are applied to the removal of compounds and elements from salt water. Thus, there is no true deep-sea mining industry today.

The major deterrent to further extension of even the shallow-water mining, to say nothing of deep-sea mining, is cost. But there is also lack of a clear picture of where and what the resources are. The problems of investigation are formidable. At present, the industry lacks efficient methods and equipment either for prospecting or mining the sea bottom, it lacks knowledgeable marine scientists and engineers, and it lacks incentive since present sources are adequate to satisfy present markets.

It has heard the reports of manganese, phosphorus, gold, platinum, tin, and a host of other minerals found on the continental shelf or the deep sea floor; but looking at the cost-benefit relationships, the mining industry is apparently obliged to wait until there has been a large-scale, long-range comprehensive program of exploration before venturing very far into this difficult region. In the national interest, the initial exploration may be the role of government.

E. Shipping

In January 1963, the active U.S. Flag Fleet consisted of 904 ships of 1000 gross tons or over with a total capacity of 13,575,000 deadweight tons. It included 21 combination passenger cargo ships, 601 freighters, and 282 tankers. 529 of these were employed in foreign trade, one in foreign-to-foreign trade, 346 in domestic trade, and 36 in other U.S. agency operations. Another 52 were temporarily laid up for repairs or awaiting cargo.

Since the Merchant Marine is subsidized, its precise value as a factor in the economy is difficult to estimate. However, it provides employment for approximately 200,000 people in seafaring, shore side, shipbuilding, and repair activities and contributes more than $5 billion annually to the domestic economy. It is estimated that it would take $10 billion to replace it with new construction.

The primary reason for subsidization is the strategic value of the Merchant Marine to national defense. It is indispensable for the emergency supply of military field activities, defense manufacturing, and essential civilian needs.

Although its numbers are slowly decreasing, the average tonnage per ship and ship speed are both increasing so that there is a slow net improvement in overall capability. Replacement policies and steps toward ship automation are intended to further this improvement.

Two oceanographic activities contribute to more efficient operations: ship routing to avoid unfavorable wave conditions, and optimizing ship hull designs to meet the specific wave and weather conditions on routes where they would be used. Both these possibilities are in the experimental or development stage but appear promising.

For example, all Military Sea Transport Service ships use forecasts of wave conditions en route developed by the Naval Oceanographic Office and issued by either the Fleet Weather Facility in Norfolk, Virginia or the comparable facility in Alameda, California. Based on an extension by Richard James (of the Naval Oceanographic Office) of basic research conducted at New York University by Neumann and Pierson in the 1950's, wave forecasting is estimated by the MSTS to save these ships an average of 18 - 20 hours per crossing, averaged over both oceans and all seasons. Over the year's total of about 1000 crossings, savings amount to about $2 million.

A similar service is available to commercial interests through several private forecasting companies. Most United States shipping companies fail to use it, however, exceptions being the States Marine Corporation and the Pacific Fruit Company, but it is patronized by European shipping concerns who do not have such a service at home but apparently like what they get here.

Extensive research on the effects of sea conditions on ship hulls, carried on for many years by the David Taylor Model Basin, the Bureau of Ships, Stevens Institute, MIT, and the Maritime Administration, has now progressed to the point where it appears that ships can be designed specifically for weather conditions along specified

routes, with improvements both in comfort and economy. It is likely to be many years before the quality of the fleet as a whole is much affected.

In this context, proposals regularly appear for consideration of a submarine tanker, or even a submarine cargo ship. It is true that, in principle, the absence of wave-making resistance would permit very large submarines to attain speeds sufficiently high to cut crossing times to the point where the high initial costs might be more quickly amortized than is the case in surface ships. But the payoff is uncertain and the date for this development is not felt to be near.

Finally, research continues on techniques to minimize the fouling of ship hulls by barnacles and marine organisms, and the associated hull roughness that reduces ship speed and increases propulsion costs.

F. Recreation Industry

Seagoing and seaside recreation has also within the last few years become a major industry. Swimming and bathing have traditionally been the most popular recreational uses of the sea, and in terms of the number of people who patronize our beaches and shore areas they still are. In terms of dollars spent in sports, however, they are far outclassed by the pleasure craft lovers. Something over 37 million Americans spent about $2.5 billion last year on boats and boating. The size of the pleasure fleet is now approximately 7-1/2 million pleasure boats, on inland and coastal waters—an increase of 500 percent over 1958; sport fishing in offshore waters has passed the half billion dollar a year mark.

The states and Federal Government are hard pressed to acquire or even preserve beach and shoreline recreation areas to meet the increasing demands. Commercial and private interests are fast acquiring choice areas and erosion is affecting many others. In recognition of the urgency of the situation, the 87th Congress authorized the establishment of three national seashores, one on Cape Cod, one at Point Reyes in California, and one on Padre Island in Texas, together totaling 127,000 acres.

Two underwater nature trails have been developed in the Virgin Islands by the National Park Service to meet the growing demand for this type of facility, and a large area called the Key Largo Coral Reef Preserve has been set aside adjacent to Florida's Pennecamp State Park.

The Bureau of Sport Fisheries and Wildlife spends nearly $15 million annually on behalf of sport fishermen, though only a small portion of this (less than 2 percent in 1963) is in oceanography.

The rising traffic of inexperienced pleasure boaters is creating a hazard to themselves and others, raising questions about how to help assure their safety. For example, there were over 3000 recreational boating accidents reported in 1961 in which over $4 million in damage was done, 1100 lives were lost, and over 1000 persons injured. Nearly 300 of the fatalities resulted from capsizings in which weather or high seas was presumably a factor, so that improved wave and storm warnings might be of some help. Marine biological research would also foster understanding of "red tides," swarms of biological organisms that kill fish and inundate and make a seashore temporarily unusable.

It is clear that the growing size of the recreation industry is a measure of the rising value of seaside and ocean-going recreation to the general public and of the increased federal responsibility to conserve it for the benefit of all.

G. Summary

Oceanographic scientists and people in the fishing, shipping, oil, mining, and recreation industries constitute groups each benefiting in some special way from oceanographic knowledge. One of these groups, the scientists, is almost wholly dependent on government support of oceanography for its livelihood. A second, fishing, cannot expect to compete in the modern world without the benefit of government supported oceanography. The oil industry owes a great deal of its recent expansion to marine geology but has obtained much of it privately. Shipping, a subsidized industry, may in the future benefit marginally if it takes advantage of certain oceanographic services such as wave forecasting. Mining is deterred from expanding into the sea by high risks and costs and, being satisfied with terrestrial resources, looks to government to underwrite the risk of marine exploration. The recreation industry is flourishing but the greatly increased recreation-seeking public is endangering its own recreation resources by overcrowding. Its full enjoyment of the sea can probably be assured only by government action to conserve this valuable resource.

Chapter IV
CAPABILITIES AND SYSTEMS TO SUPPORT OCEANOGRAPHIC GOALS

The size and scope of the overall program is based on an estimated growth in funding which averages about 10 percent per year, but which tapers from about 20 percent, from FY 1963 to FY 1964, to only about 7 percent in FY 1972. Expenditures corresponding to this expansion thus would increase from $123 million in FY 1963 to about $350 million in FY 1972, with a total over the decade of $2.3 billion. It should be emphasized, incidentally, that this plan does not represent growth over and above that which would be projected by the individual agencies in its absence. Rather, it is a simple statement of superposed needs, goals, and programs for their achievement, modulated by the act of agencies planning together.

This rate of growth, incidentally, is slightly greater than that estimated for expansion in federal support over the next decade of all scientific fields and disciplines. The annual expenditures for FY 1963 of about $12.4 billion are projected to grow to about $28 billion in FY 1972, by a factor of about 2.2. Expenditures in oceanography are estimated to grow by a factor of 2.5.

Whatever the assumed growth rate, it is essential to evaluate the compatibility between projected funds, facilities, and manpower. For planning purposes, it has been assumed that manpower in oceanographic research will increase at a rate of 9 percent per year, from a present work force of 2700 scientists to over 6000 in 1972. This figure is to be compared with an annual increase across the board in all disciplines (from education, training, field switching, etc.) that will average about 7 percent annually, for the decade. Thus, the plan anticipates a growth rate of participants in this field somewhat faster than the average for all fields; this is considered reasonable in light of the small base from which growth extends—oceanography now employs only 0.6 percent of all scientists and engineers engaged in research and development. The main problem in satisfying manpower requirements will arise out of the fact that the field should grow fastest during the first part of the next decade, whereas the production from universities will be greatest toward the end of the decade. Some temporary imbalances are bound to arise, perhaps to be met with the transition to greater emphasis on automation.

To take account both of inflation and the more sophisticated and expensive instrumentation and operations expected of the future, an annual increase of about 15 percent in the direct dollar cost of supporting each scientist has been assumed. (Since 1940, the cost per technical man year in all sciences has increased at an annual rate of about 11 percent.) Thus, research, instrumentation, and ship operations cost about $65 million in 1963. The comparable figure for 1972 is about $230 million. The number of ships in the oceanographic fleet is arbitrarily planned to increase in the same proportion as the number of scientists; that is, by a factor somewhat in excess of two. But whether in fact the capability is augmented solely by ships, or by such devices as unmanned buoys remains to be determined by research itself. The amount to be invested in facilities is similarly related to the augmentation required in the current plant to accommodate the increased work force and their activities and assumes greater increase in size of individual laboratories than in their numbers.

It is not possible to justify the allocation of this overall program among the goals and agencies by a similarly quantitative argument. The situation is more complex, depending as it must on where each agency starts as well as where it wishes to go, and most particularly on the nature of the programs which it is conducting.

To see why judgment must supplement analysis in determining the allocation of effort among agencies and programs, it should be kept in mind that many of the programs in oceanography are in essence largely determined by the questions posed for them to answer.

Such programs, and there are many, cannot be confidently assigned to the support of any particular goal nor even prorated among them. For this reason much of the accounting in this chapter, and through the entire report, has been necessarily vague. Furthermore, in the interests of brevity as well as clarity, a discussion of details has generally been omitted. What remains, though approximate, is believed sufficiently accurate to show major features, general relationships, and matters of balance

on the basis of which supplemental plans can be formulated in special fields by individual agencies and institutions. This is in keeping with the purpose of a long-range plan and the discussion in Chapter I.

In addition, such programs as the Ocean Survey Plan, the National Oceanographic Data Center, Oceanographic Forecasting System, the Navy's Oceanographic Instrumentation Center, and the like do not serve specific goals but support the entire oceanographic community. They are essentially oceanographic services of very wide and general utility, which facilitate the simultaneous attainment of national and special goals by the various agencies and the scientific community. They are therefore discussed in that context in a later chapter.

Before discussing the programs themselves, it is useful to review the overall balance of effort which they support. The way the approximately $2.3 billion tentatively planned for oceanography in the decade ahead is apportioned among the various goals was summarized at the end of Chapter II, and is further delineated in Table 1. Figure I shows the same information as well as indicating how the budget is divided among the agencies. Table 2 outlines this by functional areas as categorized by the ICO. The relative amounts, in the order in which the programs to support the national goals will be discussed in the following pages are: Strengthening basic science (56 percent of which only 23 percent is not included also in the goals following), defense (36 percent), managing resources and health hazards in the world ocean (19 percent), protecting U.S. public health (4 percent), managing resources accessible to U.S. alone (4 percent), contributing to the protection of lives and property ashore and safety of operations at sea (2 percent), and, finally, surveys and services to oceanography (12 percent)

It should be noted that the total oceanographic program has not heretofore been categorized by goals. Rather in the annual presentation of a national program, the effort has been classified according to function (research, instrumentation, ship construction, surveys, facilities, data center, and Indian Ocean Expedition) and by sponsoring agencies (Defense, Commerce, Interior, NSF,

Table 1
National Oceanographic Program 1963-1972
Fiscal Breakdown by Goals
(in percent of total)

	Basic Science	Applied Programs	Services	Totals
Basic Science (NSF)	23			23
Defense	20	16		36
World Ocean Resources	11	8		19
Health	(3)	(1)		(4)
Resources	(8)	(7)		(15)
Resources in Domestic Waters	2	6		8
Health	(1)	(3)		(4)
Resources	(1)	(3)		(4)
Protection of Safety and Property		2		2
Ashore	(0)	(1)		(1)
At Sea	(0)	(1)		(1)
Services			12	12
Totals	56	32	12	100

Table 2
National Oceanographic Program 1963-1972
Fiscal Breakdown by Functional Areas
(in Millions of Dollars)

	Research	Surveys	Ships	Facilities	Instruments	International Programs*	NODC	Total
DEPARTMENT OF DEFENSE								
Navy	370	130	255	10	60	4	6	835
Army	16							16
DEPARTMENT OF COMMERCE								
Coast and Geodetic Survey	10	90	157	3	8		2	270
Maritime Administration	1							1
Weather Bureau	9				8			17
DEPARTMENT OF THE INTERIOR								
Bureau of Commercial Fisheries	276	10	46	15	8	1	2	358
Bureau of Sport Fisheries and Wildlife	15							15
Geological Survey	30			11	5			46
Bureau of Mines	44		2		9			55
NATIONAL SCIENCE FOUNDATION	358		40	50		50	2	500
ATOMIC ENERGY COMMISSION	68							68
DEPARTMENT OF HEALTH, EDUCATION AND WELFARE								
Public Health Service	80			8				88
Office of Education	1							1
DEPARTMENT OF THE TREASURY								
Coast Guard	15	2	4		7			28
SMITHSONIAN INSTITUTION	25							25
TOTAL	1,318	232	504	97	105	55	12	2,323

*Additional funds for international programs are expended in research and survey functions, in approximately the ratio of 3 to 1

AEC, HEW, Treasury, Smithsonian Institution). It is also possible, of course, to classify the program in yet a fourth way—by major scientific discipline involved.

It is probably apparent to the reader that, whereas the effort when sliced according to any of these four systems will always total 100 percent, there is considerable difficulty in developing a detailed compatibility along all four coordinated systems that is internally consistent. In the annual program, this is only accomplished by functional area and by agency. An effort is made in this Long-Range Plan, however, to relate these two breakdowns also to the breakdown by goals.

In so doing, the reader is reminded that oceanographic effort associated with any goal includes the totality of research time, ship construction and operating costs, instrumentation, etc., that in the aggregate must be allocated to achievement of that particular goal.

Finally, what has been categorized as a goal of "strengthening basic science" should not be misinterpreted as equivalent to the conduct of "research" in the functional breakdown. The science goal sector includes an appropriate fraction of ship construction and operating costs, instrumentation, etc., but no applied research. The functional research category, on the other hand, includes both basic and applied research, and ship operating costs associated therewith, but does not include ship construction costs, facilities or major instrumentations that are catalogued separately.

A. Strengthening Basic Science (56 percent 1963-72 Effort)

If the present plans are carried out, the goal of strengthening oceanography as a science will receive a greatly increased fraction of federal support during the next ten years. Not only does the National Science Foundation intend to expand its present program almost fourfold during the decade, but the Office of Naval Research will approximately double its basic research support; the Bureau of Commercial Fisheries intends to expand its support materially in areas related to marine biology. The Smithsonian plans to spend about $25 million in basic science over the decade, and other agencies such as the Coast and Geodetic Survey and the Geological Survey will also contribute. Altogether, approximately $1.35 billion is planned to be spent during the next ten years, an expansion of more than threefold by FY 1972.

Figure 2 shows how this support is divided among the agencies. Three-quarters is administered almost equally by the Navy and the National Science Foundation, with the Bureau of Commercial Fisheries contributing another 15 percent. The remaining 11 percent is shared by the AEC, the Public Health Service, the Geological Survey, the Smithsonian, the Coast and Geodetic Survey, and the Weather Bureau.

It should be pointed out that Project Mohole is not being included in the oceanographic budget, although many of its results will be as applicable to geological oceanography and to oceanographic engineering as to geology as a whole. It is expected that other geological drillings into ocean sediments will be undertaken in water of moderate depth. None of these programs are currently included in this oceanography inventory, but future planning may suggest their addition rather than their classification of "earth sciences." While all aspects of oceanographic science will be supported, physical and biological oceanography will receive the major share.

Special international programs are included in this category of goals. The International Indian Ocean Expedition, a 32-nation, 40-ship effort begun in 1961 and expected to last until 1966 to which the U.S. is contributing 11 ships and about $24 million, and the International Cooperative Investigations of the Tropical Atlantic are examples. Basic research will be conducted principally in 35 private laboratories.

A considerable number of small laboratories and university departments also conduct basic oceanographic research, and many of these, such as the one at the Massachusetts Institute of Technology, are growing and new ones are expected to come into being. There were, in addition, approximately 12 large government laboratories and more than 20 small ones in 1963. Overall, the growth in the next decade is expected to be primarily in the number of large laboratories employing 30 or more scientists.

Private laboratories now operate a fleet of over 15 seagoing research ships and about 20 will be added to it by NSF and Navy funds in the next decade. The bathyscaph, TRIESTE, presently the only operational deep research vehicle, is operated by

the Navy. However, the Navy is sponsoring development of the ALVIN, a two-man submersible, capable of diving to 6000 feet, to be operated by the Woods Hole Oceanographic Institution. The ALUMINAUT, a three-man submersible, capable of 80-mile cruises at 15,000 to 18,000-foot depths developed and constructed with private funds, is being considered by the Navy for use in its research programs.

B. Defense (36 percent 1963-1972 Effort; 20 percent Basic, 16 percent Applied)

The oceanographic program of the Navy within the Plan in support of the national defense goal will total some $835 million over the ten-year period.

1. RESEARCH

Included in this effort are the basic and applied research programs supported by ONR, BuShips, and BuWeps. These programs not only serve to advance the frontiers of oceanographic knowledge, but also serve to advance concepts in weapons development, detection devices, and naval armament systems in general by the consideration of favorable and limiting effects of environment. These research programs have applications to pro- and anti-submarine warfare, surface strike warfare, amphibious operations, Arctic operations, mine warfare, and in the general area of logistics support, including maintenance of hulls and submerged installations and transportation of men and material. A few highlighted research areas follow:

(a) USW Research

As has been stated previously, the Navy's primary concern in oceanography relates to undersea warfare. At least six Navy laboratories currently participate in an intensive campaign of oceanographic research that includes investigations of the shape and nature of the sea floor, description of the activity and constituency of the sea itself, and the quantification of the interactions between the ocean and atmosphere related to underwater acoustics and the parameters of temperature, salinity, sea surface phenomena, etc.

(b) Other Physical Properties

Many other physical properties and phenomena, such as surface and internal waves, tides, currents and turbulence, infrared and electromagnetic properties, radioactivity, optical properties, and many individual bottom properties, have technical and design implications. Practically every bureau laboratory active in Navy oceanography participates in one or another aspect of this program which is coordinated by the Office of Naval Research.

(c) Marine Biology

Marine creatures interfere with underwater acoustic systems, influence mines and mine countermeasures, damage structures, luminesce, are poisonous, venomous or toxic, and provide clues about the presence of underwater targets. Again the Office of Naval Research coordinates this research program which includes participation of five Navy laboratories.

2. SHIPS

The second major category of Navy funding concerns construction of oceanographic ships. It is divided nearly evenly between the direct support of Navy projects and the support of interagency or privately initiated projects from which the Navy is expected to benefit in common with other participants. The quarter-billion dollars projected for ship construction is tentatively allocated as shown in Table 3.

3. MILITARY SURVEYS

The Naval Oceanographic Office carries out a program of military surveys. In contrast to the national Ocean Survey Program (described in the next chapter) which has as its objective a general strengthening of knowledge of the oceans, the military survey program is focused specifically on the Navy's operational requirements. These surveys are designed either as mapping and charting expeditions for strategic areas or to provide environmental information requisite to design installation and operation of anti-submarine warfare systems. A fleet of eight ships and a current annual budget of about $11 million supports this program.

During the coming decade 13 ships (of which seven will replace existing hulls) will be added.

TABLE 3
Navy TENOC Shipbuilding Program
(1963 through 1972)

Type	Replacements	Non-replacement	Total	Total Cost
Basic Research (1)	7	5	12	57.9
Applied Research (2)		5	5	24.1
Ocean Surveys (3)	1	5	6	48.0
Coastal and Special Surveys (4)	6	6	12	92.5
	14	21	35	222.5

(1) Assigned to private labs under ONR contract
(2) Assigned to Navy labs and NavOceano
(3) Assigned to NavOceano
(4) Assigned to NavOceano

Although data are collected for classified military operations, a very large fraction resulting from those surveys is publicly available through the National Oceanographic Data Center.

4. INSTRUMENTATION AND FACILITIES

Seven percent of the Navy's projected budget ($60 million) is allocated to development and procurement of oceanographic instrumentation. Featured in development programs will be sensing-recording-processing systems for rapid and accurate data acquisition and treatment. Part of the Oceanographic Office instrumentation budget supports the developmental effort at the Navy's Oceanographic Instrumentation Center. The remaining one percent of the budget will go toward the building of new facilities, both privately operated and military.

5. DEEP SUBMERGENCE VEHICLES

While recognizing the sea, from surface to ocean floor, is the available arena for naval warfare, most activities have been carried out at or near the surface. Combat submarines are being designed for deeper operation, but by and large the only manned vehicle for full vertical access to the ocean has been the TRIESTE. However, it has only a two-mile horizontal range. A far more ambitious study of Navy requirements is now being undertaken in relation to deep operations, including salvage.

The Navy is considering three types of vehicles, but no explicit funding is provided in this plan. The first type, designed for cruising along the continental shelf and work on bottomed equipment along the continental slope, is intended to dive to approximately 5000 feet, and cruise at slow speeds for 8 - 10 hours. Four of these are considered required early in the decade with six more later.

A second type is intended to operate to 15,000 - 20,000 feet and consequently to be able to reach bottom across 90 percent of the ocean floor. It should be able to cruise at slow speeds for as much as a day. Two of these are to be required for research prior to 1970 with two more thereafter.

The third type is intended for deep trench investigations and should go to 36,000 feet. It will probably have a limited ability to cruise at depth. A total of two of these is desired, one prior to 1970.

6. TENOC

The Navy first developed a long-range plan in oceanography in 1959, referred to as TENOC ("Ten Years in Oceanography"). Periodically updated, TENOC reflects advances in both science and operational requirements, with a balanced program organized in ten areas of effort. These areas and their relative emphasis projected over the next ten years are shown in Figure 3. However, of the Navy's total oceanographic budget of $1315 million, only $835 million, or about two-thirds, is included within the National Oceanographic

Program as categorized by the ICO. Some additional $480 million is devoted to applied research and development of a more direct military character.

The research to be accomplished by the more immediately defense-oriented portion of this plan is in four major subject areas including acoustics, magnetics and gravity, Arctic operations, and environmental forecasting.

(a) Acoustics Research

The Bureau of Ships coordinates the acoustics program, which is directed toward understanding, predicting, and exploiting acoustic propagation phenomena. This is concentrated in nine Navy laboratories supplemented by ONR-supported work in eight private and university laboratories. Many industrial organizations under contract to the Navy for sonar, torpedo, and other ASW/USW equipment also do work in oceanographic acoustics in connection with their development programs.

(b) Magnetics and Gravity Research

Programs to examine and exploit geomagnetic and gravimetric phenomena are coordinated by the Bureau of Naval Weapons. Four naval laboratories and four private oceanographic laboratories participate in this program related to submarine navigation, missile guidance and ballistics, submarine detection, and mine countermeasures operations.

(c) Arctic Research

Operations in the Arctic now require knowledge of under-ice as well as ice-edge phenomena. The Office of Naval Research coordinates work done principally in four Navy laboratories and the Arctic Research Laboratory of the University of Alaska on the Arctic oceanic environment.

(d) Environmental Forecasting

The oceanographic forecasting program, though planned to absorb only one percent of the Navy's oceanographic budget during the next decade, deserves special mention. This figure includes only the research and development aspects of programs, most of whose cost is to be borne by fleet operating and maintenance budgets. They are intended to improve the capability to forecast the ASW environment, as well as to predict the consequences of harbor flushing and disposal of nuclear products, etc.

Many of these forecasting programs will emerge from the research or experimental stage and enter the operational stage in the coming decade. The ASWEPS, for example, is expected to become operational in 1965. When it does, it will be funded by the Navy under its fleet operations budget and will not appear within the TENOC projection.

C. World Ocean Resources (19 Percent of the 1963-1972 Effort; 11 Percent Basic, 8 Percent Applied)

The two agencies primarily concerned with this goal of developing while conserving ocean resources are the Bureau of Commercial Fisheries and the Atomic Energy Commission, although the Bureau of Mines has a responsibility to study oil pollution at sea.

1. FISH RESOURCES

The Bureau of Commercial Fisheries intends considerable expansion in its basic research program during the coming decade. By 1972 about 65 percent of its total research should be basic research as compared with only about 30 percent today.

As might be expected, the distribution and nature of the various fundamental oceanographic variables and properties which define, often within rather narrow limits, the habitat of various fish will receive considerable attention. So will studies of marine communities with their patterns of dominant species, of food webs which interconnect the inhabitants of these communities, and of rates of energy and food transfer throughout these webs. Ecological balances must be thoroughly understood before the consequences of man's intrusion on them can be predicted.

Studies of particular species already or potentially useful to man will be continued, and a major program of technological and engineering research will be undertaken to improve present methods of locating, catching, preserving, and preparing fish for the table. In this connection a program of economic, legal, and social studies will be undertaken as basic to the management and mar-

keting problem. That this last is not trivial is illustrated by the availability of some wholesome fish foods in considerable quantities which are presently wasted due to local conventions or legal restrictions. Finally and of much interest to both marginal fish industries and underdeveloped nations bordering on the sea, a program devoted to increasing the yield of the sea itself is planned. Introducing new species into at present unoccupied food niches in the marine community, modifying the environment to favor food fish over predators, placing fish shelters on areas with barren bottoms, and the addition of trace elements and nutrients to fertilize the oceans, at least locally, are all under study.

To carry out this program, the Bureau of Commercial Fisheries estimates it requires 25 new ships in addition to the 20 now operating in oceanography and seven new laboratories. By the end of the decade, they should have a total of 41 ships, considering retirements, and 27 laboratories. In addition, they expect to have a medium-depth underwater research vehicle, a mesoscaphe, which they will share with the Bureau of Mines. Their proposed expenditures over the ten-year interval would run somewhat over $350 million.

2. WORLD HEALTH

The Atomic Energy Commission has monitored radioactive contamination produced by detonation of nuclear devices, wastes from reactors, and effects from nuclear-powered ships since 1944 when the first materials were introduced into the environment. Since then the disposal of packaged wastes in both the Atlantic and Pacific by several nations has occurred in amounts sufficient to warrant continued close routine monitoring and the refinement of limits on maximum permissible concentration. Future hazards from accidents involving nuclear propulsion systems, both waterborne and missile-connected, are under study, as is the prediction of the consequences from nuclear detonations of all kinds. The research program concerns the appearance and distribution of radioactivity in marine organisms, in the sea itself, and in the sediments and rocks under the sea, through chemical as well as physical and biological processes. It is of necessity mainly basic rather than applied and is expected to run about $68 million over the next ten years. The AEC plans to build no ships of its own but will continue to use those of other agencies.

3. COOPERATIVE ASPECTS

Although increasing competition and conflict are possible in man's increasing use of the world ocean for its fish and to dispose of his wastes, the possibilities of cooperation for mutual benefit and the support of underdeveloped nations are also great. The past history of regulation of the whaling, halibut fishing and fur sealing industries augurs well for future accommodations among the competitive nations. The potentialities of surveys and studies in direct support of the fisheries of such underdeveloped nations as the Ivory Coast and Nigeria have only partially been realized. In addition to improving the material well-being of such nations, a cooperative program enlisting nationals of such countries as participants could serve to introduce them into at least one aspect of modern science and perhaps pave the way for further scientific progress in other fields. The International Indian Ocean and the Tropical Atlantic expeditions currently dominate the international oceanographic picture, although other international programs are in various stages of development.

D. Management of Resources in Domestic Waters

1. PROTECTION OF U.S. PUBLIC HEALTH
(4 Percent 1963-1972 Effort;
1 Percent Basic, 3 Percent Applied)

Closely allied to the preceding goal is the direct protection of the health of the U.S. public from industrial or radioactive wastes and other forms of pollution. The AEC program, particularly that concerned with monitoring and studying the effects of reactor wastes carried to sea by rivers, makes a contribution to this goal, but it is the Public Health Service which carries the main effort.

The Public Health Service oceanographic activities are an integral part of a continuing program of research on health hazards and of the environment taken as a whole. The oceanographic aspects center on water pollution surveys and shellfish sanitation and are carried out in close connection with state programs. During the next ten years, the Public Health Service will focus

studies in particular locations on the Columbia River, Delaware River, Susquehanna River, and Chesapeake Bay, with new studies beginning after 1965 of the Southeast Drainage Basins and the Alaska Drainage Basins.

The program should total about $88 million in the next ten years. Three new facilities will be added to the present nine conducting oceanographic projects. No ships are required.

2. MANAGEMENT OF U.S. RESOURCES HELD IN COMMON

(4 Percent 1963-1972 Effort, 1 Percent Basic, 3 Percent Applied)

Although a comparatively modest effort, the funds for investigating and managing the resources along the shore and on and under the continental shelf represent such an increase from the small amount being spent on this area today (less than 1 percent) that a considerable change in the picture of what these resources are should develop by 1972. The Geological Survey and the Bureau of Mines plan a systematic exploration of this potentially valuable area for mineral deposits. The Bureau of Commercial Fisheries will continue to study such local food resources as clams, oysters, lobsters, and the like, and the Office of Saline Water is prepared to participate or advise as needed. The Bureau of Sport Fisheries and Wildlife, the Bureau of Outdoor Recreation, and the National Park Service expect to concern themselves with recreational values.

The Geological Survey plans to establish two new major oceanographic research centers closely tied to its Washington (D. C.) and Menlo Park (Calif.) geological research centers. From these centers, it will study the composition, structure, geologic and hydrologic processes, and resources of the ocean floor, in cooperation with other government agencies and private institutions. The studies will permit offshore extension of geological and geophysical knowledge of land areas and will provide a better understanding of sedimentary rocks and resources that were formed beneath the oceans and subsequently raised above sea level to form lands. Current emphasis is being placed on estuaries, bays, continental shelves and other nearshore areas of the United States, its possessions and trust territories. As knowledge of these areas becomes available, the emphasis will be extended seaward to the deep oceans.

The Bureau of Mines proposes the construction of a marine research center at an as yet unspecified shoreside location with provisions for process laboratories for sea water extraction and mineral separation studies, core libraries for specimen storage, analytical facilities for sample determinations, and docking space for research vessels, instrument shops, and the like. In addition to the mesoscaphe which it will share with the Bureau of Commercial Fisheries, the Bureau of Mines will require a number of specialized surface and underwater craft or devices for drilling, dredging, and taking piston cores. Both the Geological Survey and the Bureau of Mines will need extensive new instrumentation. By the end of the decade the Bureau of Mines expects to have various underwater mining demonstration laboratories. The preparation of an ocean floor mine shaft will be investigated with initial drifts, a mine shaft collar to the ocean surface, an elevator, and various underwater shelters at the mine opening. Under study are floating underwater laboratories for seagoing research operations and on-the-spot analysis and testing. Bureau of Mines and Geological Survey programs should run in the vicinity of $100 million for the ten-year period.

With regard to the resource represented by the recreational value of the seas and shores, the Bureau of Sport Fisheries and Wildlife expects to add one research center on the Gulf of Mexico to the two it now operates and to provide research vessels for each to take the place of the chartered ships now in use. Its program emphasizes the inventory of game fish populations, determining particularly suitable locations for game fishing, and the development of sea water systems at each of its three research laboratories for holding game fish and rearing their young.

The oceanographic effort on behalf of recreation is expected to run about $15 million over the decade.

E. Safety at Sea, Protection Ashore

1. PROTECTING LIFE AND PROPERTY ALONG THE COASTLINES (LESS THAN 1 PERCENT OF THE 1963-1972 EFFORT)

The Army's Corps of Engineers (with the Beach Erosion Board as one of its research agencies) plays the major role in protecting beaches and

harbor areas from wave-attack, and in providing navigation channels and harbors in the coastal area, while the Weather Bureau issues warnings of the occurrence of dangerous conditions from storms. Both will continue their research programs at about present levels throughout the decade. This is expected to amount to about $16 million for the Corps of Engineers and to be slightly under $3 million for the Weather Bureau.

In the Pacific, the tsunami warning service of the Coast and Geodetic Survey will be improved and expanded as part of an international program to extend the greatly needed warning to other areas of the Pacific. Further research will also be undertaken in an attempt to learn to forecast the wave heights as well as times of arrival. The Coast and Geodetic Survey plans to allocate about $1 million to this effort in the coming decade in a cooperative venture with other nations.

2. SAFETY OF OPERATIONS AT SEA (1.2 Percent 1963-1972 Effort)

The traditional responsibility of the Coast Guard for maritime safety and the maintenance of navigational aids at sea has always led to activities of great use and value to oceanography. While conducting the International Ice Patrol and such regulation enforcement operations as the Bering Sea Patrol, and while conducting icebreaking operations in the Arctic, its ships have usually accommodated scientists from other agencies and laboratories and carried oceanographic and meteorological instruments of various sorts. It was especially fitting that in the Fall of 1961 the Coast Guard's charter was formally amended to authorize the conduct of oceanographic research within the agency itself, in relation to its mission. During the coming decade, its program will support work in connection with such diverse goals as ocean survey program, inshore surveys, studies of ocean waves and swells, ice in the sea, oceanographic forecasting, radioactivity in the oceans, and oil pollution of navigable waters. Two new oceanographic ships and much new instrumentation represent major requirements for their expanded role. Their oceanographic budget is expected to run about $28 million over the ten years.

As to promoting safety at sea, the chart and map service of the Naval Oceanographic Office and the Coast and Geodetic Survey are of vital importance. Additionally, they serve as the necessary base maps for other scientific investigations. These products, and the surveys to provide the data on which they are based will be continually improved and updated throughout the period.

F. Services (12 Percent 1963-1972 Effort)

These will be described in more detail in the next chapter. They are mentioned here as important activities in support of the entire oceanographic community from which all benefit in common. Although a smaller fraction of effort during the next decade than at present, they do in fact represent an expansion over the present program. Much of this expansion is in the Ocean Survey Program conducted by the Coast and Geodetic Survey primarily in association with the Navy but with participation of the Coast Guard, the Bureau of Commercial Fisheries, the Geological Survey, and the Weather Bureau. The Coast and Geodetic Survey will require eight new ships and the Navy four for this operation. Buoys, also under development for the ocean survey program, could add greatly both to the effectiveness (and probably to the cost) of the program if they are successfully developed and optimally employed.

An oceanographic forecasting service for non-military use may come into the program during this period. Its costs and requirements cannot yet be estimated. It would presumably benefit from—and probably resemble—the Navy's ASWEPS program.

The National Oceanographic Data Center, already an integral part of the national community, will continue at a slightly expanded rate, and a new facility, the Naval Oceanographic Office Instrumentation Center, recently established by the Navy, will function to some extent in support of the entire community. In advancement of the concept of coordinated effort, the oceanographic units of a number of federal agencies have moved, or are in process of moving to a three-acre area in the Washington, D. C. Navy Yard Annex.

The Interagency Committee on Oceanography feels that there may be a need for one or more interagency marine centers where interdisciplinary programs beyond the capacity of single agencies could be carried on. No firm plans for such centers exist as yet, however.

G. Instrumentation

The instrumentation requirements for the programs just described are generally similar—and formidable. At the same time, technology and engineering promise at last to provide much that has long been lacking. They are, therefore, discussed together, although the funds planned for them have been included in the agency budget figures already given.

It has been difficult to keep oceanographic instrumentation in step with technological advances in other areas for two major reasons. One is that the need for high precision while being used in a very harsh environment places extreme demands on a designer's skill. Temperatures must be correct to the nearest .01 degree Celsius and salinity to the nearest two parts in a hundred thousand over pressure ranges from one to perhaps 1000 atmospheres if density determinations made from them are to be correct to the nearest part in a million, as is required for the study of some physical processes. Other instruments, such as thermal probes to measure heat flow through the sediments at the bottom, depth recorders, sonic probes, plankton collectors, and audio-visual devices for fish observations and surveys and the like, have similar extreme demands on their quality.

The second reason for the archaic state of oceanographic instrumentation is that this demand for high quality is coupled with little demand for quantity. As a consequence, there has been little incentive for heavy investment in their development by those industries most competent to advance the state-of-the-art. As a result, most instruments were originally designed, built, and even manufactured in such quantity as needed by versatile oceanographers themselves. The numerous Nansen devices, still in use after 50 years, the bathythermograph, and the Ekman current meter, are all examples, excellent of their kind yet hardly to be compared in engineering sophistication with recent products of the space industry. Telemetering, data processing, communications, and other back-up systems could all be improved, as could almost every device now in use.

Development during these next ten years is expected to emphasize increased speed and efficiency of standard measurements rather than the creation of devices for obtaining new types of information. In addition to automating many of the shipboard procedures now carried out tediously by hand, the Navy, Coast and Geodetic Survey, Bureau of Commercial Fisheries, Coast Guard, and the Weather Bureau are seeking automated fixed stations for sensing and transmitting oceanographic data remotely on a routine basis.

Instrumentation for marine biology has lagged even farther behind than that for other aspects of marine science, and particular effort will be made to develop more satisfactory plankton recorders, sampling gear, and underwater camera and television equipment. A so-called "parameter follower" is being sought by several agencies. This device, intended to be towed or self-propelled, would sense a given concentration of one parameter and remain within it while recording variations in others. It is expected to be particularly helpful in fish migration studies, simulating some of the important behavior patterns of migrating fish.

Moored buoys with strings of current meters for obtaining extended records at a given point have been in use for several years. The present models require retrieval in order to obtain the data, and this has proved both time consuming and unreliable. Developing moored buoy systems to accommodate a variety of instruments and telemeter data first to the surface and then to shore stations, aircraft, or satellites has therefore been an attractive possibility. The Office of Naval Research has been conducting a systems study program for the last two years on various configurations and alternatives.

These studies have determined an optimum size and configuration for a system capable of telemetering data at the rate of 300 bits per minute on an intermittent schedule with high reliability over a distance of 2500 miles while remaining unattended for up to a year. Prototypes are under construction together with a shore command station, mooring techniques are being developed, and oceanographic sensors are being designed. A complete buoy system should be available at the end of about two more years. The program is being guided by an advisory committee of the ICO consisting of research oceanographers as well as experts in buoy technology and representing private institutions as well as the Navy. This development program is estimated at about $3 million.

Other smaller buoys for specialized purposes have been developed with ONR support at both

Scripps Institution of Oceanography and the Woods Hole Oceanographic Institution for a number of years and this work will continue.

Many agencies are contemplating plans based on the use of anchored buoy stations in rather large networks within the next few years. Before these plans are executed, three important interim steps should be taken. First, the development program should be carried to the point where sensors are reliably capable of long unattended operation and the buoy can be counted on to hold its moorings and transmit significant amounts of information over the required distances. No buoys have these characteristics at present and much more expensive development is required. Second, once such buoys are available, none should be installed until the time space data sampling requirements are thoroughly worked out. These requirements depend on the scientific question being asked, the process to be studied, and the scale characteristics of other processes also capable of producing sensor responses appearing as "noise" in the data record. The noise must not obscure the signal. Finally, efforts under way at the international level to establish legal and operational conventions must be completed.

Figure 4 shows the relative effort contributed to the instrumentation program by the various agencies. The Navy expects to carry three-fifths of the planned total of $103 million, reflecting a massive effort to expedite solutions of problems of packaging sensing-recording-processing systems, to perfect deep diving exploration vehicles, and to overcome sound attenuation. The remaining two-fifths will be fairly evenly divided among the Bureau of Commercial Fisheries, Geological Survey, Bureau of Mines, Coast Guard, Weather Bureau, and the Coast and Geodetic Survey. Particular efforts are therefore being made to assure thorough exchange of information among the agencies concerned by the establishment of a central file of instrumentation data at the National Oceanographic Data Center, the publication of an encyclopedia of oceanographic instruments, and the joint agency use of the Navy's Oceanographic Instrumentation Center at the Navy Yard Annex in Washington, D.C.

H. Manpower

A final capability on which all else depends is an adequate corps of trained, imaginative, and skillful scientists. No other problem in basic oceanography currently warrants greater attention than the manpower problem, and this in spite of the fact that the ranks of oceanographers are expected to continue to grow at a rate moderately in excess of the national average for scientists as a whole. This projected growth in oceanography of about ten percent where the national increase in all types of scientists has averaged about seven percent is the basis for the programs now planned in pursuit of the national goals in oceanography. Meeting these requirements is expected to result from the continued transfer of scientists from other basic fields such as physics, geology, chemistry, biology, mathematics, and engineering since fewer than 100 degrees in oceanography are granted each year. The greatest educational shortages are projected to lie in the areas of physical and meteorological oceanography, although systematic biologists, marine geophysicists, and geochemists are also scarce. Other types of marine biologists and geologists are currently being trained at an adequate rate. Two attacks on the problem currently being mounted involve motivation at lower academic levels and increased application of training grants.

In one respect, the large number of transfers from other fields is desirable. It provides a cross-fertilization of ideas which is particularly valuable in oceanography where many of the processes of greatest interest are best dealt with from a multidisciplinary point of view. As oceanographic frontiers are pushed back, more and more specialized knowledge in an increasing variety of technologies and fields of knowledge is required to help solve the novel problems which keep turning up, and to devise new "tactics" to surmount unprecedented difficulties.

On the other hand, the "strategic" approach to oceanographic knowledge to assure its advance over a broad front can hardly be certain without the creative activity of a large number of people broadly trained and widely experienced in oceanography itself.

In the light of this situation, the direct support provided by the National Science Foundation, and the Departments of Interior and HEW for fellowships and training grants in oceanography might seem small, especially since the ten-year projection shows little increase over the period. However, the problem is strongly cyclic and self-limiting. Uni-

versity departments have more than their share of trouble attracting oceanographers already in short supply anyway and temperamentally more interested in research, particularly seagoing research, than they are in teaching. They tend to go to the great oceanographic institutions such as Woods Hole and Scripps where research receives major emphasis. It is a rare university which can combine both types of facilities. They might produce still more if they retained more of their graduates in teaching positions rather than losing them to research, but this would produce an even greater deficit of research oceanographers during the interim. The best way to prime the educational pump in oceanography is one of the subjects greatly in need of study during the coming years and is a high priority item for one of the panels of the Interagency Committee on Oceanography.

Chapter V
SURVEYS AND SERVICES

Some programs and activities in oceanography are undertaken to meet needs felt more or less strongly by each group within the oceanographic community but which are beyond the capacity of each to meet separately or of any to provide for all. Among these are broad area surveys, the maintenance of a complete library of oceanographic data, the testing and calibration of a variety of instruments, including novel ones, and forecasting oceanic conditions of both research and operational interest.

The first two of these are present realities as are ice and wave forecasting. The Ocean Survey Program, described in ICO Pamphlet No. 7, ultimately may be a part of an international effort as described in the next chapter. It has already begun in a small way with the closely controlled underway lines and the network of oceanographic stations conducted in the North Pacific by the Coast and Geodetic Survey's PIONEER in 1961.

The second service type activity is the National Oceanographic Data Center (NODC) which was established two years ago to assemble, process, archive, and disseminate to interested users all oceanographic data collected anywhere. Both these programs were endorsed and implemented through the Interagency Committee on Oceanography.

The Navy has just established its own Oceanographic Instrumentation Center and steps are being taken to make this available to users on a national basis. The Navy's ASWEPS (Anti-Submarine Warfare Environmental Prediction System) is expected to become operational around 1965. It may also provide some nonmilitary applications.

A. The Ocean Survey Plan

Both the scientific community, through the National Academy of Sciences Committee on Oceanography, and the various federal agencies have expressed the need for systematic mapping of the major properties of the oceans, the basins which contain them, the sediments which lie under them, the forces such as gravity and magnetism which permeate them, and the life which they contain. Such mapping can, of course, serve a variety of goals, providing tools for use in military and economic welfare, as well as in scientific oceanography. The measurements of interest to each federal agency, the areas for early investigation (limited for some time by the availability of Loran C precision navigational aids), and the 1964 ship assignments are presented in ICO Pamphlet No. 12, May 1963. Detailed discussion is presented in the ICO "Ocean Survey Plan," ICO Pamphlet No. 7, May 1963.

The ship requirements for an ocean survey program cannot be exactly determined, since the desired rate of progress cannot be established except on subjective and intuitive grounds. Furthermore, the actual rate of progress which various survey ships will demonstrate, once assigned, cannot be precisely estimated. Presumably much can be done to make present operations more efficient if the ship is designed and equipped for participation in a coordinated program than would be the case if its survey work were done in isolation. Finally, the value of information collected from survey lines taken at close intervals, say ten miles apart, as compared to that which would result from lines 20 or even more miles apart must be weighed against the differences in cost or time associated with each. It is possible that buoy developments may proceed rapidly enough to replace some ship survey effort late in the time period. The economic and effectiveness considerations involved here have not yet been analyzed.

Both the need and the magnitude of the job will never be greater than at present, however, and it is the present intention to proceed with an orderly survey program as rapidly as funds and personnel will allow. The Coast and Geodetic Survey, acting as agent for the ICO, has awarded a contract for a major planning study of optimal survey systems and their deployment. As estimated now but subject to reconfirmation as plans mature, the next decade should see 24 new survey ships—16 built by the Navy to serve both in the ocean survey program (5) and for special military surveys (11) and eight by the Coast and Geodetic Survey (primarily for the ocean survey program). These plans will be responsive to new developments in instruments, particularly in buoys which may multiply the unit effectiveness and permit much more rapid prog-

ress, and to progress in cooperative plans with other nations. The present estimate is that the ultimate share of the United States in the world ocean survey will be approximately 30 percent (to be prosecuted mainly by the Naval Oceanographic Office and Coast and Geodetic Survey with assistance from other agencies).

The program planned here is expected to run about $260 million over the decade.

B. The National Oceanographic Data Center

The need for a centralized repository for the Nation's oceanographic data has been recognized for many years. Action began about four years ago to establish such a facility and the 86th Congress originated, but failed to pass, a bill establishing a National Oceanographic Data Center. At the same time, the federal agencies through the Interagency Committee on Oceanography recommended a jointly sponsored center to the Federal Council for Science and Technology and this was approved in June of 1960. In November, the NODC was established as an administrative component of the Navy's Hydrographic (now Oceanographic) Office, and began work under the policy guidance of an interagency Advisory Board representing the six supporting agencies* and the National Academy of Sciences. Steps are being taken to assure close communication with ICO by having the NODC Advisory Board Chairman report the activities of the Center to the Chairman of the ICO.

NODC functions as a service activity for all segments of the Nation's scientific community with respect to marine environmental data and information requirements. It also makes these data accessible to the general public free of charge or provides copies at cost.

In performing this function NODC must, of course, receive, compile, process, and preserve oceanographic data in a form permitting rapid retrieval. It thus establishes procedures for insuring that the accuracy and general quality of the data meet the criteria established by an Advisory Board. Finally, it prepares data summaries, tabulations, and atlases showing annual, seasonal, and monthly oceanographic conditions. The technical problems in carrying out these functions adequately are formidable, and all the resources of modern data handling technology as well as an informed understanding of the oceanographic community's needs are being brought to bear.

Housed in downtown Washington in the former Naval Weapons Plant, the National Oceanographic Data Center has a staff of approximately 80. Its budget during the next ten years is expected to total approximately $15 million. About half of this is presently borne by the Navy, and most of the remaining half is evenly divided among the Coast and Geodetic Survey, the National Science Foundation, and the Bureau of Commercial Fisheries. The Weather Bureau, the Atomic Energy Commission, the Coast Guard, the Geological Survey, and the Department of Health, Education, and Welfare each contribute about two percent.

C. The Navy's Oceanographic Instrumentation Center

Although the Oceanographic Instrumentation Center is a Navy activity, it cooperates with other government agencies, private industry, and the academic community to bring about improvements and refinements in instrumentation, serving their needs to the extent possible. It is an attempt on the part of the largest user of oceanographic instruments to assure that the data it obtains about the oceans is precise and accurate.

After a slow evolution in the 1950's, the Navy's Oceanographic Office Instrumentation Division blossomed into the present Center in November 1962. It has a staff of about 100 engineers, scientists, technicians, and supporting personnel. It contains engineering facilities for laboratory and contractual development, test, and evaluation, and the maintenance of instruments. It is developing such new instrumentation as improved electronic bathythermographs, shipboard wave recorders, a shipboard survey system, submerged buoy systems, and sound velocimeters.

Its test equipment is extensive and modern, including pressure test vessels, shock and vibration test equipment, tensile test facilities, pressure and temperature tanks, reversing thermometer calibration equipment, a 60-foot clear-water instrument test tower, and a small craft for environ-

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*Navy, Coast and Geodetic Survey, Bureau of Commercial Fisheries, the National Science Foundation, the Atomic Energy Commission, and the Weather Bureau.

ment testing in local waters. It intends to provide engineering advice and assistance to agencies and activities on oceanographic instrumentation matters, and to serve as a clearing house for information on the oceanographic instrumentation development program.

Its budget, which is borne by the Navy, is expected to total approximately $30 million over a ten-year period.

D. Oceanographic Forecasting Service

The Navy has two environment and wave forecasting programs which could conceivably lead to developments of interest to nonmilitary users. They are instrumented to handle on a fully automatic basis incoming bathythermograph and sea surface temperature observations and to issue charts of the depth of the upper isothermal layer and the surface temperature variation. The major limitation is the crudeness of the present data inputs so that its outputs are relatively unsophisticated, but improvements are continuing and they provide valuable supplements to the ASWEPS program, scheduled to become fully operational sometime after 1965. Standing for Anti-Submarine Warfare Environmental Prediction System, ASWEPS is intended to provide forecasts of a a large variety of oceanographic variables of particular significance to the operating forces. These variables will describe in considerable detail the ocean environment in at least the upper layers. It is hoped that enough information about the sensors, installations, prediction techniques, data processing know-how, and various automation methods can be made available for the development of a parallel nonmilitary system, or that the Navy system can also serve some nonmilitary users on a not-to-interfere basis.

Very approximate estimates of the cost of developing a world-wide ASWEPS system run about $3 million annually for the R&D phase, totaling $20 million. Operating costs will run very nearly another $3 million a year thereafter.*

E. Summary

The oceanographic service of greatest magnitude planned for the next decade is the Ocean Survey Program. It should contribute to the goals of all the agencies, the scientific community, and other special groups such as the fishing and mining industries. Of international importance, as is noted subsequently, it is expected to reflect about one-third of a planned international effort. Costs amount to approximately $240 million including the construction of 12 new ships.

Other services whose growing importance is out of all proportion to their comparative small costs are the National Oceanographic Data Center and the Navy's Oceanographic Instrumentation Center.

The Navy's ASWEPS will provide an important capability to forecast oceanographic conditions for military purposes. The possibility of providing some nonmilitary services or of establishing a nonmilitary counterpart is under consideration.

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*Not included fiscally in the National Oceanographic Program.

Chapter VI
THE INTERNATIONAL SETTING

Many of the considerations which have led the United States to its recently intensified interest in the sea have similarly motivated other nations as well, and in many cases for much longer. As each has sought to learn more about the sea, it has quickly come to realize that the sea is very large and its own unaided efforts very small. As far back as 1899, a conviction that effective exploration of the sea based on sound scientific principles demanded international cooperation led to the formation of the International Council for the Exploration of the Sea (ICES). Established by eight nations* to conduct a joint exploration of the North Atlantic, the North Sea, the Baltic Sea, and the adjacent waters, the ICES raised and tentatively settled such important issues as the standardizing of techniques and instruments and the exchange of data.

The International Geophysical Year is the most recent major manifestation of the tradition of international cooperation in scientific exploration of the oceans. It was both the result and the cause of a great number of international organizations for scientific cooperation, both governmental and private. UNESCO, which had sponsored the development of many intergovernmental associations, established the Intergovernmental Oceanographic Commission (IOC), in 1960, with a membership list of 40 countries, including the United States. The IOC held its First Session in October 1961, with attendees from most member countries and from many of the 26 international scientific organizations which showed an interest in oceanographic problems. Two other United Nations bodies, the Food and Agriculture Organization (FAO) and the World Meteorological Organization (WMO), and one nongovernmental organization, the Scientific Committee on Oceanographic Research (SCOR) of the International Council of Scientific Unions, were the three most closely identified with the IOC's purpose and have maintained close working relationships with it ever since.

The IOC's Second Session in September 1962 added four more nations to its membership list and extended its already long list of proposed projects for international cooperation. It assumed coordinating responsibility for the International Indian Ocean Expedition, originally organized and coordinated by SCOR, with SCOR continuing to act in an advisory capacity. It agreed to undertake the International Cooperative Investigations of the Tropical Atlantic Ocean, as suggested by the United States, and is actively making plans to start two closely related projects, both suggested by the USSR. These are a standard section program to study time changes in characteristics of the oceans and a North Atlantic expedition for studying fields of currents by dynamic techniques. In addition, it concerns itself with the perennial questions of standardization, intercalibration, and the exchange of data as well as some of the more particularly modern problems such as the legal status of fixed buoys, frequency allocation for telemetering and other communications, and the availability of new aids to navigation such as Loran C and the Transit satellite system under development by the United States.

Not the least important aspect of such activities is the opportunity they provide for scientists and technicians from nations without research ships and facilities of their own to participate and to further their own training while contributing to the collection of knowledge which is itself of mutual benefit.

The United States, with 11 ships already committed to the Indian Ocean Expedition and five more to the Tropical Atlantic Expedition, plans to put somewhere between $70 million and $90 million into such cooperative programs during the coming decade. The Interagency Committee on Oceanography, at the request of the State Department, is the United States point of contact for activities related to the IOC. United States participation in these programs is based on requirements which we would otherwise have to pursue alone. By joining our efforts with those of other nations with similar needs, we not only foster friendships and common interests among the collaborators, but greatly increase the scientific benefit which we, like the other participants, realize for the effort which each has expended.

It is not possible to determine with any great accuracy the present size and scope of specific

*Denmark, Finland, Germany, Great Britain, Netherlands, Norway, Russia, and Sweden.

foreign oceanographic programs. Like ours they are changing in both respects. Up-to-date figures are not always available even when free access to official information is granted, and in the case of the USSR, the program of perhaps greatest size and interest, this access is not free. Also, definitions are not uniform. For example, foreign programs show about three technicians for every scientist where the U.S. shows only one. Perhaps a third or more of the foreign technicians might be classed equally well as scientists, effectively doubling the numbers given in the sections which follow. What is known, however, indicates that the United States, the USSR, Japan, the United Kingdom, and Canada, lead the other nations of the world in the extent and quality of their programs.

It has been the declared intention of the President and the Congress that the U.S. should maintain world leadership in this field of science. The following discussion should help illuminate this country's present position in terms of size, scope, and quality. In a field where so much opportunity exists for new discoveries, there is never room for complacency.

A. USSR

The USSR is reputed to have more than 60 - 70 ships available for oceanographic research though undoubtedly many of these do double duty as mother ships for fishing fleets or act as icebreakers and as naval escorts or supply ships. Their fishing fleet of over 3000 vessels, deployed to fishing grounds all over the world, presumably contributes to the collection of oceanographic data also. It is also likely that many of their merchant fleet, now consisting of something over 1000 ships and growing rapidly, take observations of near-surface oceanographic conditions as well as reporting meteorological conditions into the world synoptic weather net.

Their best known research ships are the MIKHAIL LOMONOSOV, built in 1957 of about 5960 displacement tons with some 16 oceanographic laboratories and space for about 75 scientists on board; the VITIAZ, similar in size though built in 1939; the SVERYANKA, a research submarine; and the 12,000-ton OB, built in 1953. In addition to these floating laboratories, two other large ships of about 4600 tons, the PETR LEBEDEV and the SERGEY VAVILOV, were refitted in 1960 while the SEVASTOPOL, a 2500 tonner, has been in the research fleet since 1951. The ZARYA, a small sailing ship, is the world's only nonmagnetic research vessel. The exact size of their professional oceanographic scientific staff is not known but is estimated at about 500 - 700 scientists and about 1600 technicians, thus considerably smaller than that of the U. S. Their work is of broad scope and generally high quality. It is of interest to note that the Soviet Interdepartmental Coordination Scientific Council on the study of the oceans and seas is somewhat similar in concept to the ICO.

B. Japan

The Japanese effort in oceanography is now estimated to have passed that of Great Britain and to rank behind only those of the U. S. and the USSR. It has traditionally been concerned with the problems of fisheries, shipping, and protection against marine catastrophes such as tsunamis, storm surges, and typhoons. These preoccupations, natural to an island nation with a dense population, little arable land, and modest mineral resources, have resulted in a strong emphasis on applied research and a program conducted almost entirely within the governmental meteorological, fisheries, and hydrographic agencies. Though some 16 or so universities have facilities for oceanographic and fisheries studies, their role in Japanese oceanography has been primarily educational. In addition to excellent fisheries research, Japanese oceanography has long been considered to excel in air-sea interaction studies, tsunami prediction, sea water chemistry, and problems of the Kuroshio current dynamics.

Recent developments indicate a trend towards more basic research and broader scope. A new Oceanographic Institute devoted to basic research is planned for Tokyo University, and two research vessels of about 300 tons are to be built for its use. Greater emphasis on physical, chemical, and geological oceanography can be expected in the future.

This broadening interest is already manifest in the recently initiated program of "Japanese Expeditions to the Deep Sea," a continuing series, four of which have already taken place.

Japan's traditional willingness to participate in international surveys and expeditions, as well as

her growing interest in deep sea oceanography, is shown by the assignment of five out of her approximately 24 survey and fisheries research vessels to the International Indian Ocean Expedition. This fleet is comparatively new, three-quarters of it being less than 12 years old. It is also very capable, with six of the ships exceeding 1000 tons and only two under 200 tons in size.

The Oceanographic Society of Japan includes more than 500 members, and the work force is estimated at 200 - 225 professionals with about 600 technicians. Some 30 - 35 students graduate with bachelor's degrees in oceanography each year but only four or five doctorates are conferred. The annual oceanographic budget is estimated at about $10 - $12 million.

C. United Kingdom

It was the British "Challenger" Expedition in 1873-1876 which first opened the oceans of the world to modern science, and the British have maintained a leading place in world oceanography ever since.

British oceanography centers in the work of the National Institute of Oceanography, generally considered one of the outstanding oceanographic institutions in the world. It was founded in 1949, in Surrey, to centralize the work of three older establishments—the Discovery Committee, the Oceanographic Branch of the Admiralty, and the Underwater Sound Establishment at Teddington.

The work at NIO emphasizes physical oceanography, including wave studies and current measurements, but its program also includes some marine chemistry, sea-floor geology, geophysics, and marine biology. Its staff is led by some 20 senior scientists, and its major oceanographic vessel is the new DISCOVERY. Its operating budget has risen from about $3/4 million in the middle of the last decade to about $1.8 million today.

The Ministry of Agriculture and Fisheries conducts a program of applied oceanography at its laboratory in Lowestoft, operating the research vessel ERNEST HOLT. The Fisheries Biology for Scotland has a laboratory in Aberdeen, and the Marine Biological Association has a laboratory in Plymouth.

Education and research in physical oceanography is conducted at the Department of Oceanography at Liverpool where the University also maintains the famous Tidal Observatory. The Department of Geodesy and Geophysics at Cambridge conducts ocean-floor studies, and some eight additional universities have recently initiated programs also in marine geology. The British Museum and the British Petroleum Company also have programs in geological oceanography.

Large-scale hydrographic survey work is conducted on a world-wide basis by the Admiralty with a survey fleet of about ten.

There are about 300 professional oceanographers in the United Kingdom supported by about 900 technicians. Some 40 - 45 bachelor's degrees in oceanography are granted each year, but only 5 - 6 doctorates. The ocean-going research fleet includes about 16 vessels and the annual budget is estimated at about $8 - $10 million.

D. Canada

Canada conducts a large, well-rounded program in all phases of oceanography but with special application to the Arctic and sub-Arctic. A central Canadian Committee on Oceanography, representing both universities and government agencies, establishes basic policy and coordinates the research program through four working groups, each concerned with a different geographical area.

There are approximately 170 professional oceanographers and 500 technicians working in a total of about 14 laboratories. The Canadian research fleet consists of 17 vessels including several refitted icebreakers, and ships normally operated for the Fisheries Research Board. The annual budget is estimated at about $58 million.

E. Summary

The international apparatus for cooperative oceanographic enterprises is large, active, and highly effective. The member nations with the greatest capabilities are the United States, the USSR, Japan, the United Kingdom, and Canada, but there are 39 others represented as well. It is estimated that more than 250 oceanographic research ships exist capable of open ocean operations and that there are numerous smaller enterprises as well as the Ocean-Wide Survey Plan that can best be executed through international cooperation.

Chapter VII
PROGRAM SUMMARY AND EVALUATION

The national plan in oceanography for the next decade is in its gross features an extension of the trend established during the last five. Yet in many ways, it also represents something new.

What is new is hard to measure since it is precisely what is most uncertain. It includes continuously recording instruments which will permit survey ships to make measurements under way, new submersibles for exploring the ocean at all depths, new buoy systems for quasi-permanent installation over great areas and new satellites for interrogating them and relaying their stored up data to shore stations for analysis, new forecasting systems for the major oceanic variables of interest to fisheries and to shipping as well as to scientists, new ways of mining the ocean floor, new ways of hunting, herding, achievement of an underwater pest control (through interference with the food chain), and even cultivating fish, and perhaps even a new habitat for workers in underwater laboratories and communities. These are new tools on the one hand and new applications on the other. What is new, in other words, is the coming technology. What this plan attempts to provide, therefore, is an oceanographic establishment of men, ships, and facilities and a program of research and development which is ready and able to capitalize on whatever may materialize out of the coming technology and to apply it to the furthering of our national goals.

The establishment which is being planned can best be seen in graphical form. Figure 5 shows the budget trend which is continued over the next ten years. The national budget of under $10 million in 1953 represents the relatively small effort devoted to the field until very recently. In 1958, it had increased only $20 million. The increase from that point on has been at a rate of nearly $100 million in five years and projecting this into the future brings the overall annual figure to about $350 million by 1972.

Some changes in the way the budget is allocated, however, are expected to take place during the decade. Figure 6 shows the 1963 allocation, both by goal and by agency, and Figure 7 shows the projection for 1972. Most evident is the great expansion in the portion of the effort which supports basic science. It rises from some 43 percent of the budget today to about 57 percent in 1972. The support for defense has decreased in percentage from 44 percent to 32 percent while the effort put into resource and health management in the world ocean has increased from 15 percent to 24 percent.

The oceanographic fleet is expected to change as is shown in Figure 8. There are 76 ships in it today. If the projections of this plan materialize, there should be over 120 by 1972. In addition, there may be a fleet of six to eight submersibles capable of exploring all depths of the oceans.

The major marine laboratories, of which there are now 63, should have grown to some 85 by 1972 as shown in Figure 9. The 26 which are operated privately today should have been joined by another 10 to total 36 by this time while government laboratories are expected to increase in number from 37 to 49.

With these tools we should be able to make major advances in our basic understanding of the oceans, and the next decade is expected to see a great improvement in our ability to forecast and use oceanographic conditions for military advantage and to increase the yield of fish which the sea contains. With international cooperation a good start should have been made in surveying the oceans and their basins and in mapping the distribution of major properties. Most of the mineral resources on and under the continental shelves should have been located and assayed.

At least, that is the plan. How can the plan itself be evaluated? The terms for such an evaluation were suggested in Chapter I. They can be summarized in the following questions:

Has the plan been able to avoid —
- duplication and waste,
- overlooking opportunities for new joint enterprises made possible by centralized planning, and
- inconsistency between goals, programs, and resources?

Does the plan —
- justify the balance of effort among the various goals,
- show the long lead-time items in perspective, both as to requirements and worth,
- indicate major possibilities as yet uncertain but worth working for,

point out prerequisites for success likely to be overlooked as well as important alternatives which should be supported as insurance against failure of major efforts,
provide a comparison with like efforts abroad, and
criticize its own shortcomings and indicate the remedy for future revisions?

Does it provide a sufficiently clear basis for action (or reaction) in its support by —
the public,
the scientific community,
the Congress, and
the Executive Branch?

The answers to these questions ought to be "yes." But candor compels that it be at best, "well, partly." Duplication and waste do not seem to be evident on the interagency scale this plan is concerned with, but it has been impossible to confirm this at levels of greater detail. The work of an individual agency often contributes to several goals, and most goals require the support of several agencies, but coordination at the interagency level is felt to be generally effective in minimizing duplication and waste. Thorough documentation is not possible.

Mention has been made of ICO hopes for joint marine centers where enterprises of an interdisciplinary and interagency nature might be undertaken. Since the need or utility of such centers has not been thoroughly documented as yet, nor is it being formally studied, it is not yet clear whether this may be an opportunity made possible by centralized planning which is in danger of being overlooked.

One possible inconsistency between goals and programs has been revealed. Unless the program for training new manpower for oceanography is more successful than seems likely at present, one or more of the federal goals will suffer through dilution of the quality of the work force. The most vulnerable is the goal of strengthening basic science and the most likely encroachment is from defense. Unfortunately the manpower problem is only partly solvable at the federal level, being strongly dependent on actions by universities and by individuals now outside the field. The present federal program should be carefully reviewed, however, to see whether more is possible.

Ships and facilities, the longest lead-time items, seem roughly in balance with the goals they are to support, the rest of the programs of which they are a part, and with each other. The net gain of about 50 ships which is planned over the decade together with the approximately \$104 million in new facilities to be built averages overall to somewhat more than the ratio of \$1.5 million in facilities for every new ship in the fleet which was recommended by the National Academy of Sciences Committee on Oceanography. Whether this will work out to be a proper balance in the way each is deployed is impossible to estimate at the moment.

The comparison with oceanographic programs abroad was made to the extent the limited information allowed. It was limited to the present, rather than projecting into the future, and was less than adequate in the case of the USSR. With the possible exception of the USSR, the United States effort appears to exceed considerably that of the other world leaders in oceanography—Japan, the United Kingdom, and Canada. All are sufficiently small, however, in comparison with their objectives to make international cooperation highly beneficial to each.

The major deficiencies in this plan appear to be those which can be remedied by more extensive and systematic analysis of alternatives, choices, and their consequences. The ICO is not at present in a position to remedy this defect without some strengthening, and how this might be done will be discussed in the next chapter. Finally, whether what has been presented here is of value to the scientific community, to Congress, and to the general public, only they can determine. The hope that this will prove to be the case, however, has strongly motivated the effort which this document represents.

Chapter VIII
ORGANIZATIONAL PROBLEMS

The President, with advice and assistance of the new Office of Science and Technology, is responsible for government-wide program planning and coordination. In oceanography, the Director of OST, who serves as Chairman of the Federal Council for Science and Technology, looks to the Interagency Committee on Oceanography to carry out this activity. The present Chairman of the ICO is the Assistant Secretary of the Navy (Research and Development), and ICO membership includes eight federal bureau chiefs. It carries out its functions through special panels on Research, Surveys, Instrumentation and Facilities, Manpower and Training, International Programs, and Ship Construction. It is an organization which is built on the skills and competence found in the departments and which provides a means for the expression of many points of view. It is considered more workable and responsive to the diverse and complex requirements of the broad spectrum of oceanographic management problems than would any single executive department vested with the same responsibility, an alternative which is sometimes suggested.

Its panel structure is highly effective in identifying technical needs in various research categories, devising programs and measures to meet these needs, identifying desirable allocations of technical effort among the agencies and suggesting assignment of technical leadership, and facilitating interagency communication at management levels.

The ICO itself reviews these panel findings and recommendations, assures an appropriate division of technical effort, examines the balance of effort among the different research categories and the adequacy of the overall program, makes findings concerning the technical manpower base for the program, and recommends management policies to improve the quality and vigor of the effort.

Government-wide plans and programs, budgets and organizational recommendations are reviewed and approved by the ICO's parent body, the Federal Council for Science and Technology, based on analyses developed by staff and consultants of the Office of Science and Technology.

The ICO depends on the individual agencies to evaluate the scientific worth of projects within their own programs.

Including as it does technical, operating, administrative, and scientific people on the committee and its panels, and functioning as it does within the framework of the Federal Council for Science and Technology, it has been able to avoid both paralysis on the one hand and superficial and hasty action on the other, the two fates on which most committees founder. Nevertheless, deficiencies and difficulties exist. Two in particular seem worth noting.

Although it has been highly successful in establishing effective communications at the management level, the ICO needs to do more to improve communications among the scientists, engineers, and others at the working level. It has published numerous pamphlets and bulletins on the results of panel work of general interest: an annual interagency plan, yearly ship operating schedules, college curricula, Ocean Survey Plan, etc. This series is intended to continue and to be extended. It also intends to publish an encyclopedia of oceanographic instrumentation. Being considered, but not yet at the planning stage, are interagency marine centers in which interdisciplinary programs of large scope could be carried on more efficiently with pooled facilities than they could on a single agency or laboratory basis. Finally, there is a possibility that something of value might result from ICO-sponsored interdisciplinary conferences organized perhaps around particular goals in oceanography, such as the federal goals discussed in this plan or those of special seagoing groups such as fishing, shipping, and mining. The ICO, through its present panel structure, is probably already capable of this extension of its activities if it should undertake this effort.

Second, to improve its own effectiveness in decision-making and in planning, the ICO should have the support of a small full-time analytical staff in addition to its Secretariat. The staff should, in effect, work for and be responsible to the Chairman of the Committee. It should be responsible for systematic analysis which will aid in planning,

on both a short-term and long-term scale, and assisting in the development and application of criteria for evaluating of research and development projects and programs. Funds should also be provided for studies, where necessary, to draw on competence outside the Federal Government.

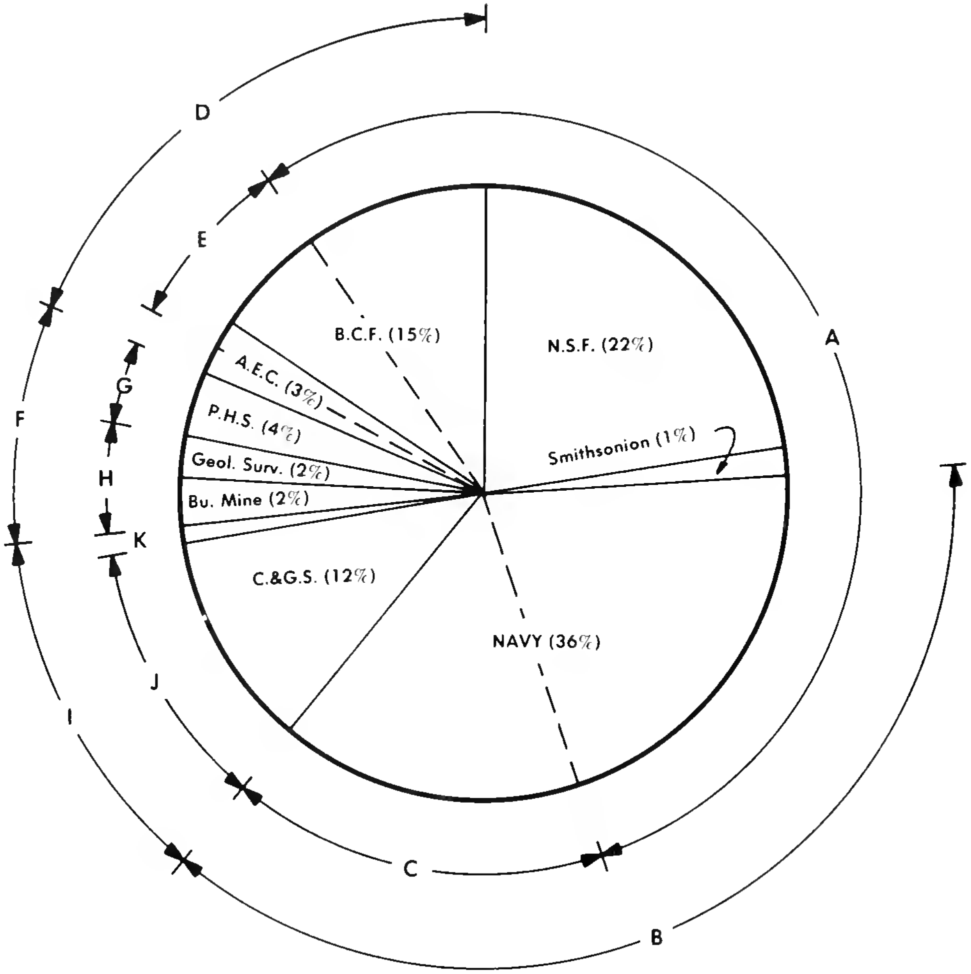
Both communication and staffing problems will become more severe as the program of growth described in this plan materializes, and their solution is therefore a matter of some urgency.

Finally, a word should be said on leadership of the program presented here. The ability of federal agencies and their boards and committees to make wise decisions for implementing the plan depends critically on the quality of the scientist-administrators who hold posts of leadership. Their own scientific experience and ability should be sufficient to understand clearly the scientific impact of their decisions, and their judgment should be clear enough to realize at the same time that the basis for their decisions in cases of conflict is pragmatic, not scientific, that the goals that guide them are national or agency goals, not scientific ones. It is therefore of utmost importance that the Federal Government attract scientist-administrators of this type into agency service.

BY AGENCY

1. Navy (36%)
2. National Science Foundation (22%)
3. BuComm. Fish (15%)
4. Coast & Geodetic Survey (12%)
5. Pub. Health Service (4%)
6. Atomic Energy Com. (3%)
7. BuMines (2%)
8. Geol. Survey (2%)
9. Smithsonian (1%)

Others
- Coast Guard
- Weather Bu.
- Army, Corps of Engineers
- Bu Sport Fisheries & Wildlife
- Maritime Ad
- Office of Ed.



BY GOAL

A. Basic Science (56%)
B. Defense (36%)
C. Defense Applied (16%)
D. World Ocean Resource Health (19%)
E. World Ocean Resource Health Applied (8%)
F. U.S. Resource, Health (8%)
G. U.S. Health (4+%)
H. U.S. Resource (4%)
I. Services (14%)
J. Surveys (12%)
K. Protection of Property, Safety at Sea (2%)

Figure 1 - National Oceanographic Budget FY 1963 - 1972

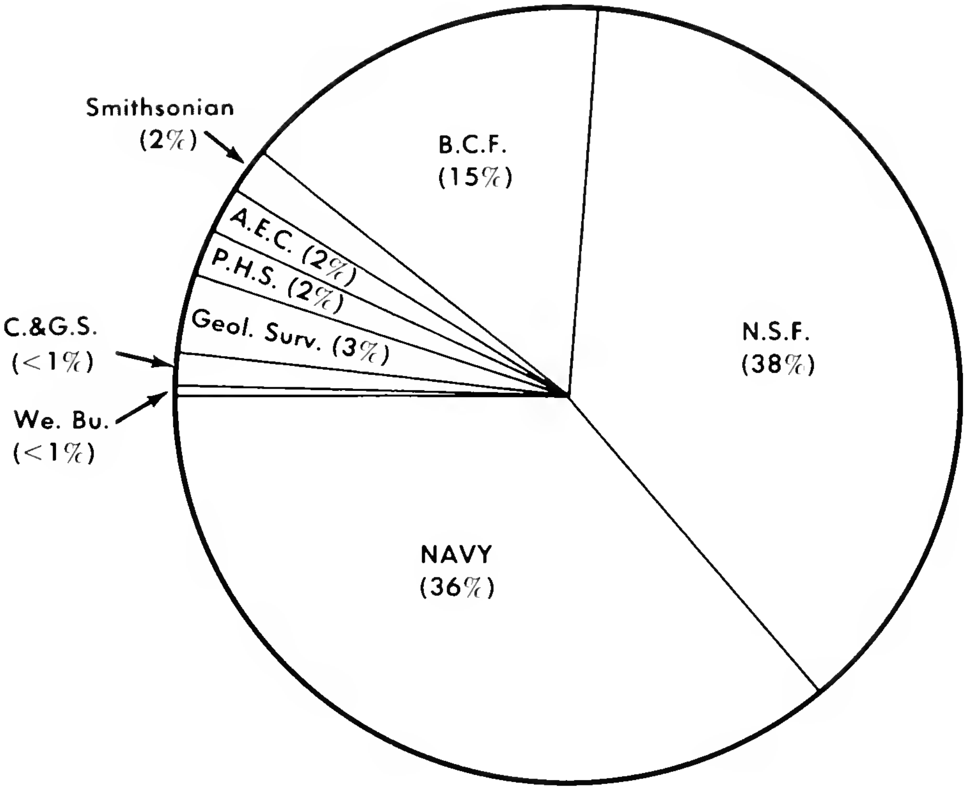


Figure 2 - Federal Support of Research

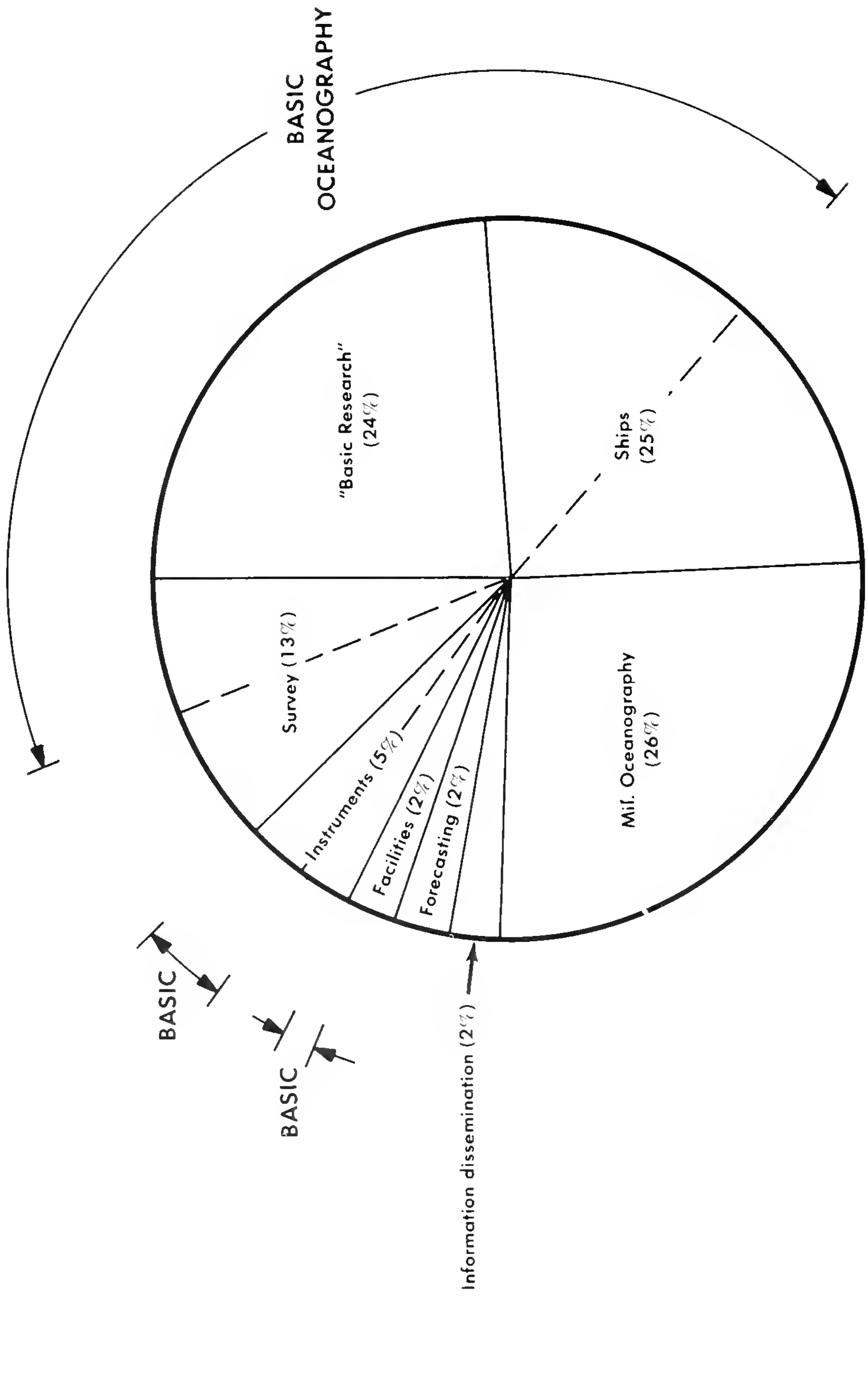


Figure 3 - Navy TENOC Budget by Function

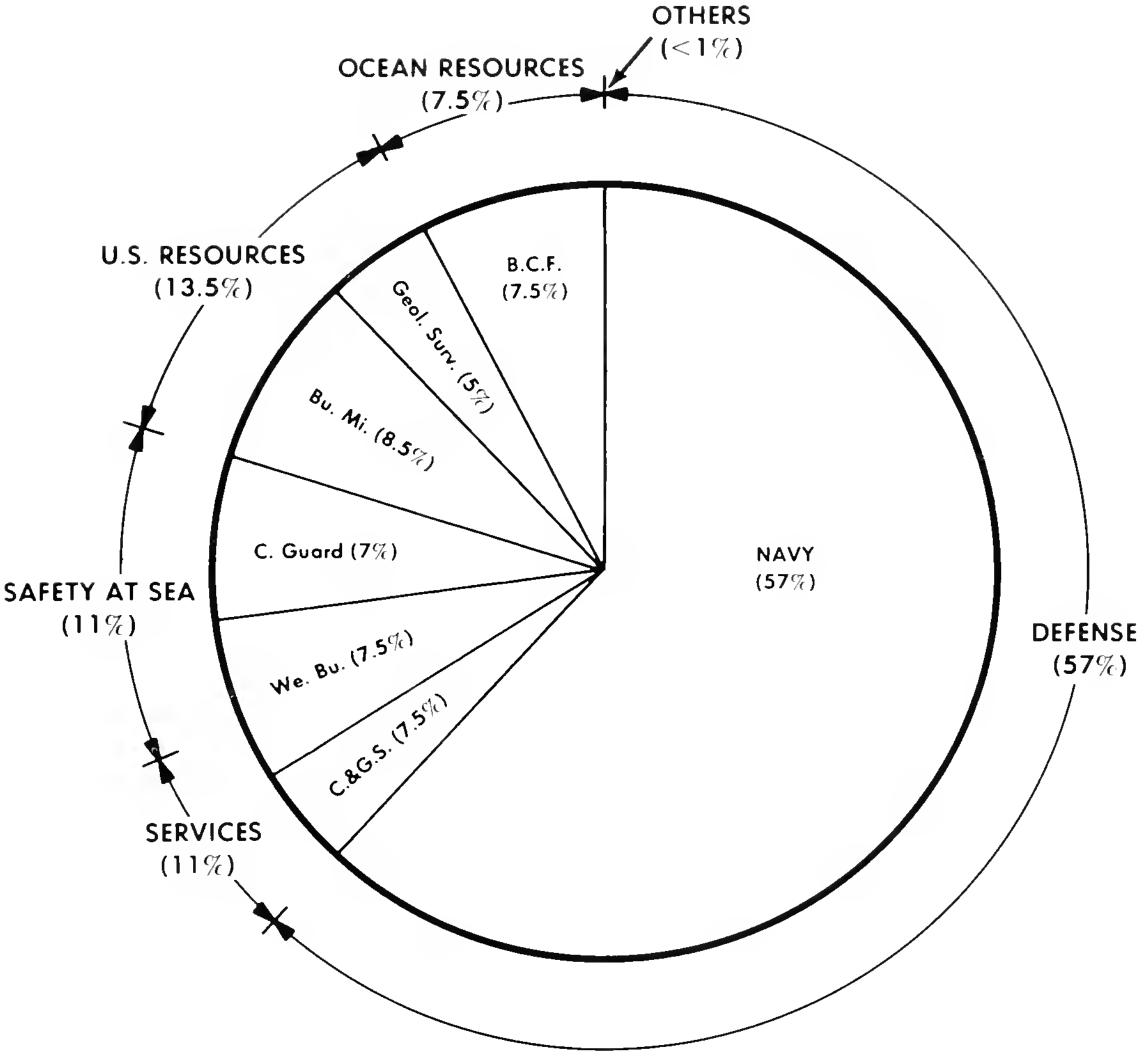


Figure 4 - National Instrumentation Budget, Comparative Years

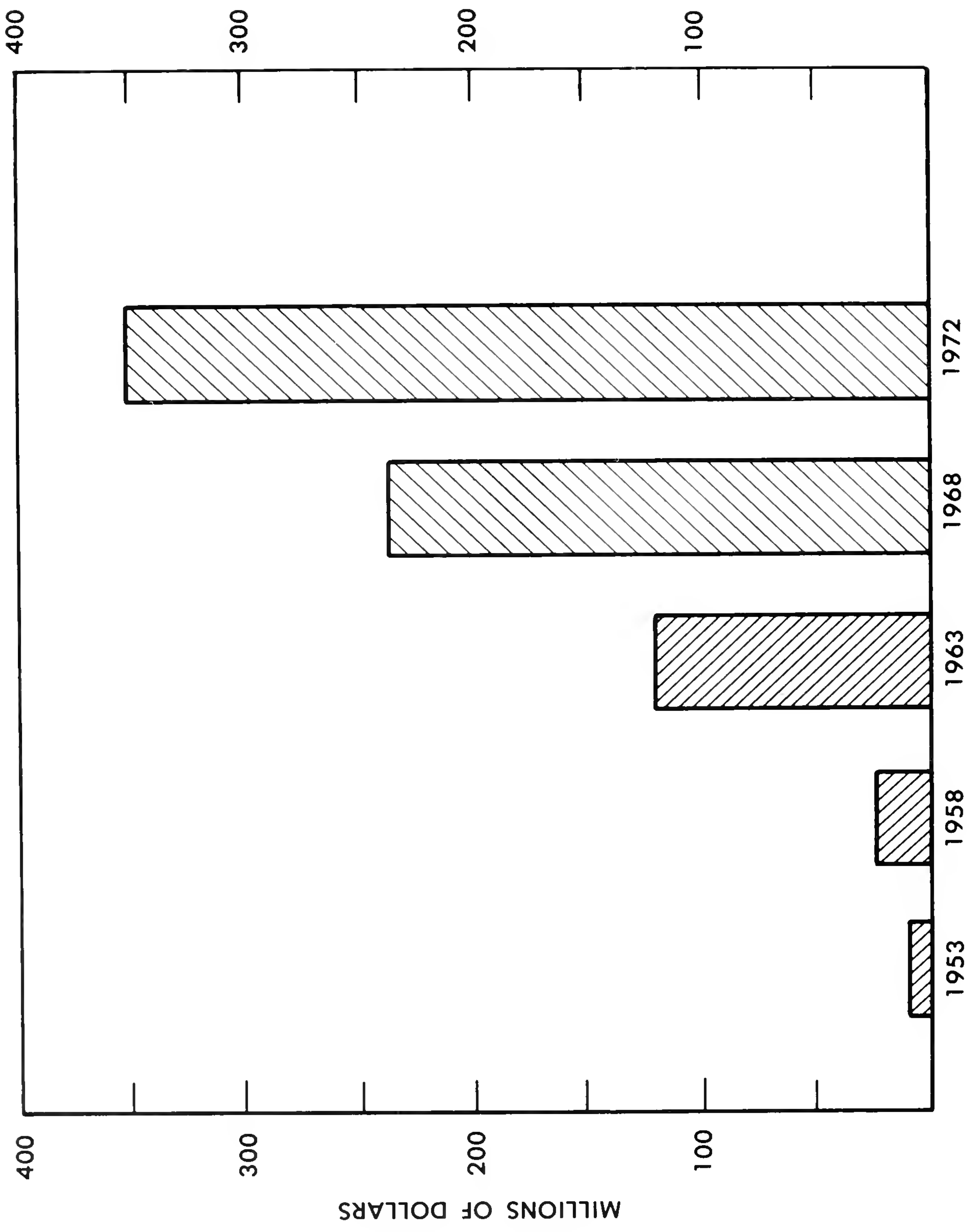


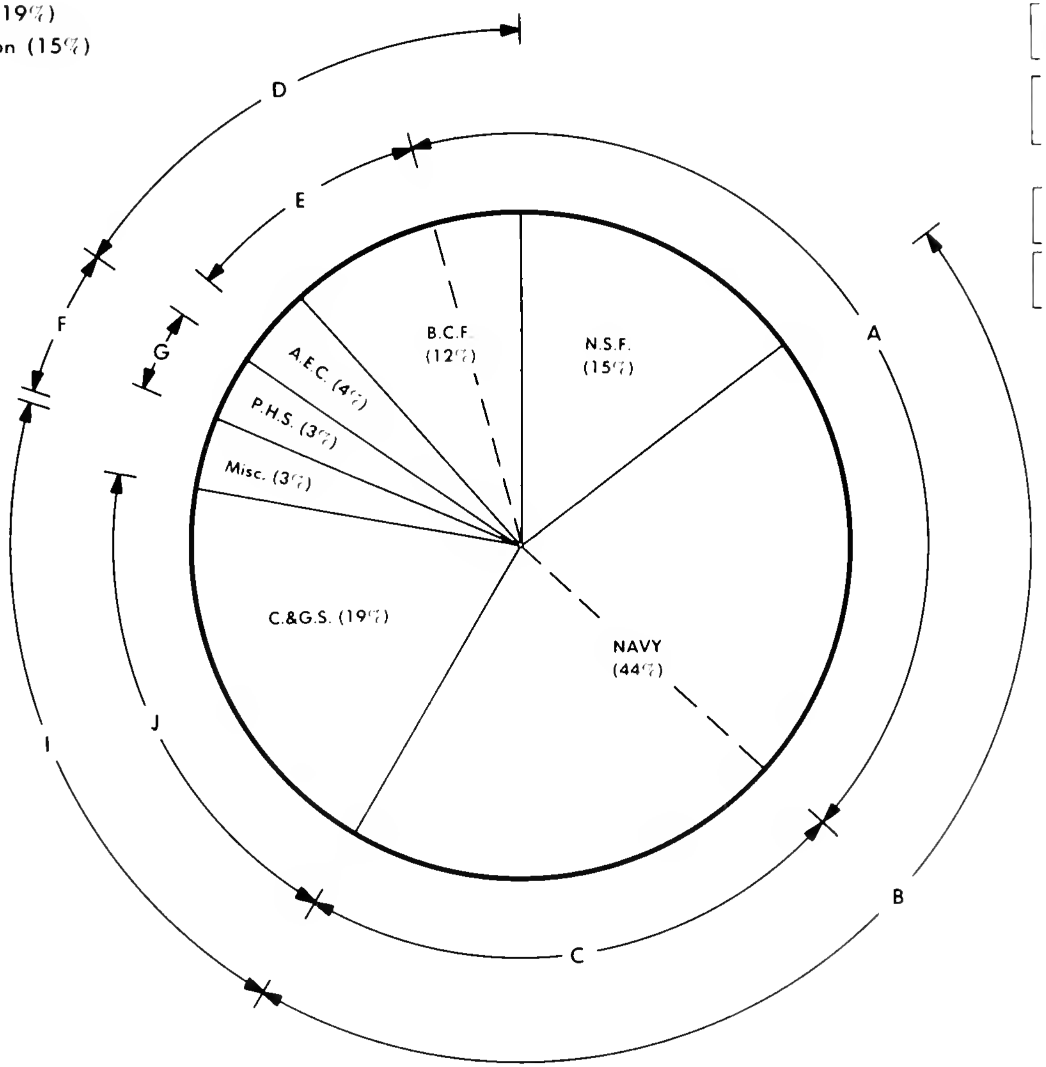
Figure 5 - National Oceanographic Budgets, Annual Projections

BY AGENCY

1. Navy (44%)
2. Coast & Geodetic Survey (19%)
3. National Science Foundation (15%)
4. BuComm. Fish (12%)
5. Atomic Energy Com. (4%)
6. Pub. Health Service (3%)

Others (3%)

Coast Guard
Weather Bu.
Army Beach Erosion Board
Geol. Surv.
BuMines
Bu Sport Fisheries & Wildlife
Smithsonian
Maritime Ad.
Office of Ed.



BY GOAL

A. Basic Science (43%)
B. Defense (44%)
C. Defense, Applied (22%)
D. World Ocean Resources, Health 315%)
E. World Ocean Resources, Health Applied (9%)
F. U.S. Resources, Health (6%)
G. U.S. Health (4%)
I. Ocean Services (20%)
J. Ocean Surveys (19%)
K. Protection of Property, Safety at Sea

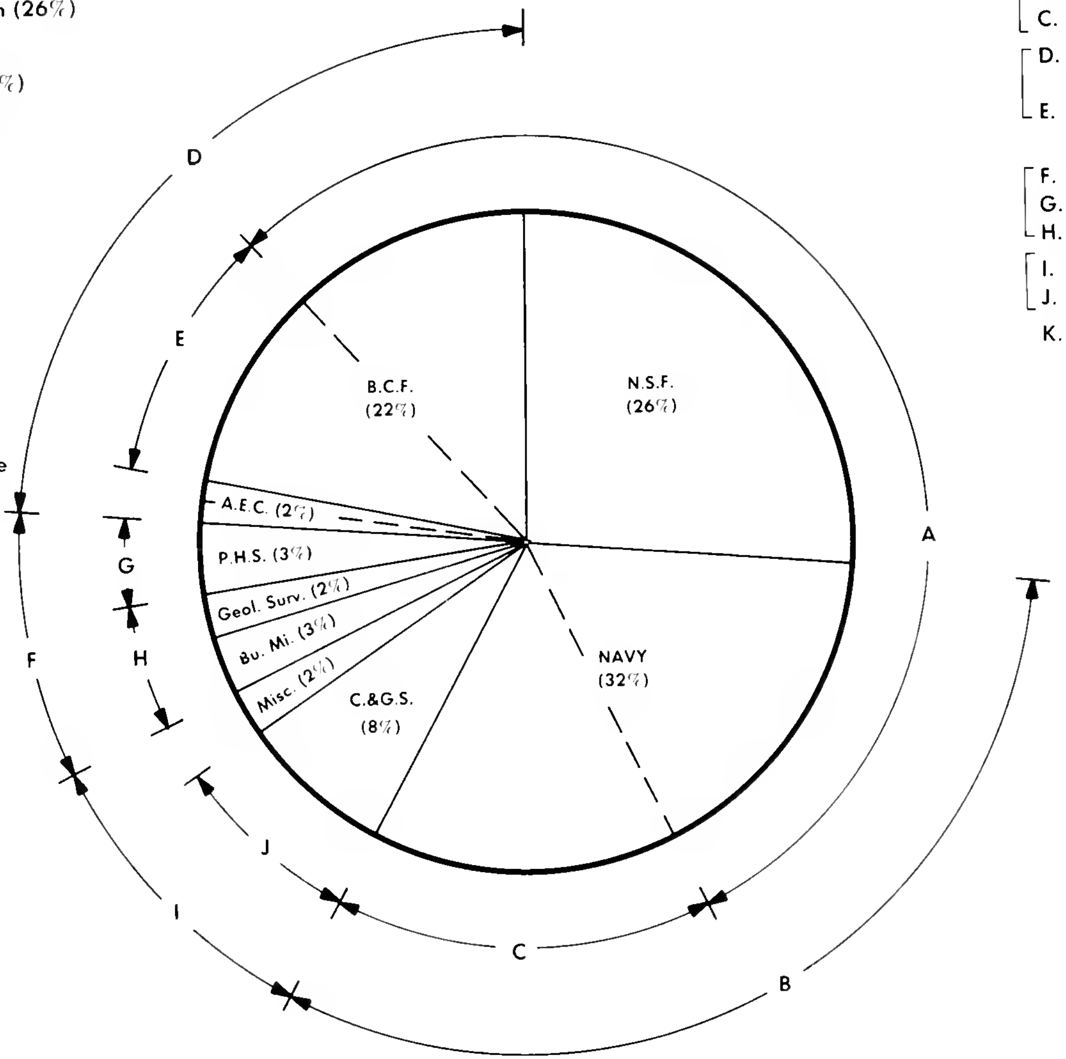
Figure 6 - National Oceanographic Budget 1963

BY AGENCY

1. Navy (32%)
2. National Science Foundotion (26%)
3. BuComm. Fish (22%)
4. Coost & Geodetic Survey (8%)
5. Pub. Health Service (3+%)
6. Atomic Energy Com. (2+%)
7. BuMines (3%)
8. Geol. Survey (2%)

Others (2%)

Coast Guard
Weother Bu.
Army Corps of Engineers
Bu Sport Fisheries & Wildlife
Smithsonian
Maritime Ad.
Office of Ed.



BY GOAL

A. Basic Science (57%)
B. Defense (32%)
C. Defense, Applied (15%)
D. World Ocean Resources, Health (24%)
E. World Ocean Resources, Health Applied (12%)
F. U.S. Resource, Health (8%)
G. U.S. Health (3%)
H. U.S. Resource (5%)
I. Services (10%)
J. Surveys (8%)
K. Protection of Property Safety at Sea

Figure 7 - National Oceanographic Budget 1972

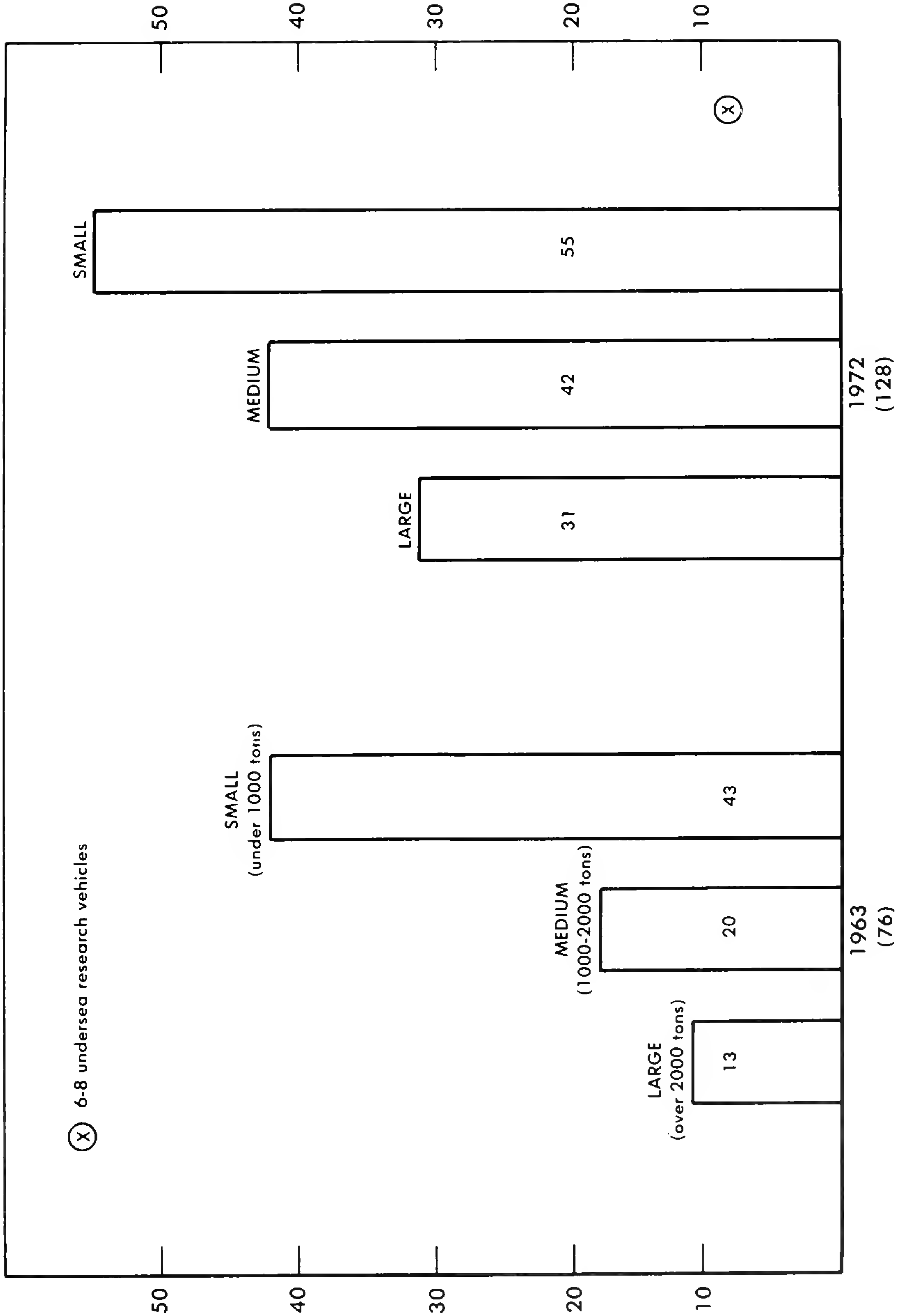


Figure 8 - National Oceanographic Fleet

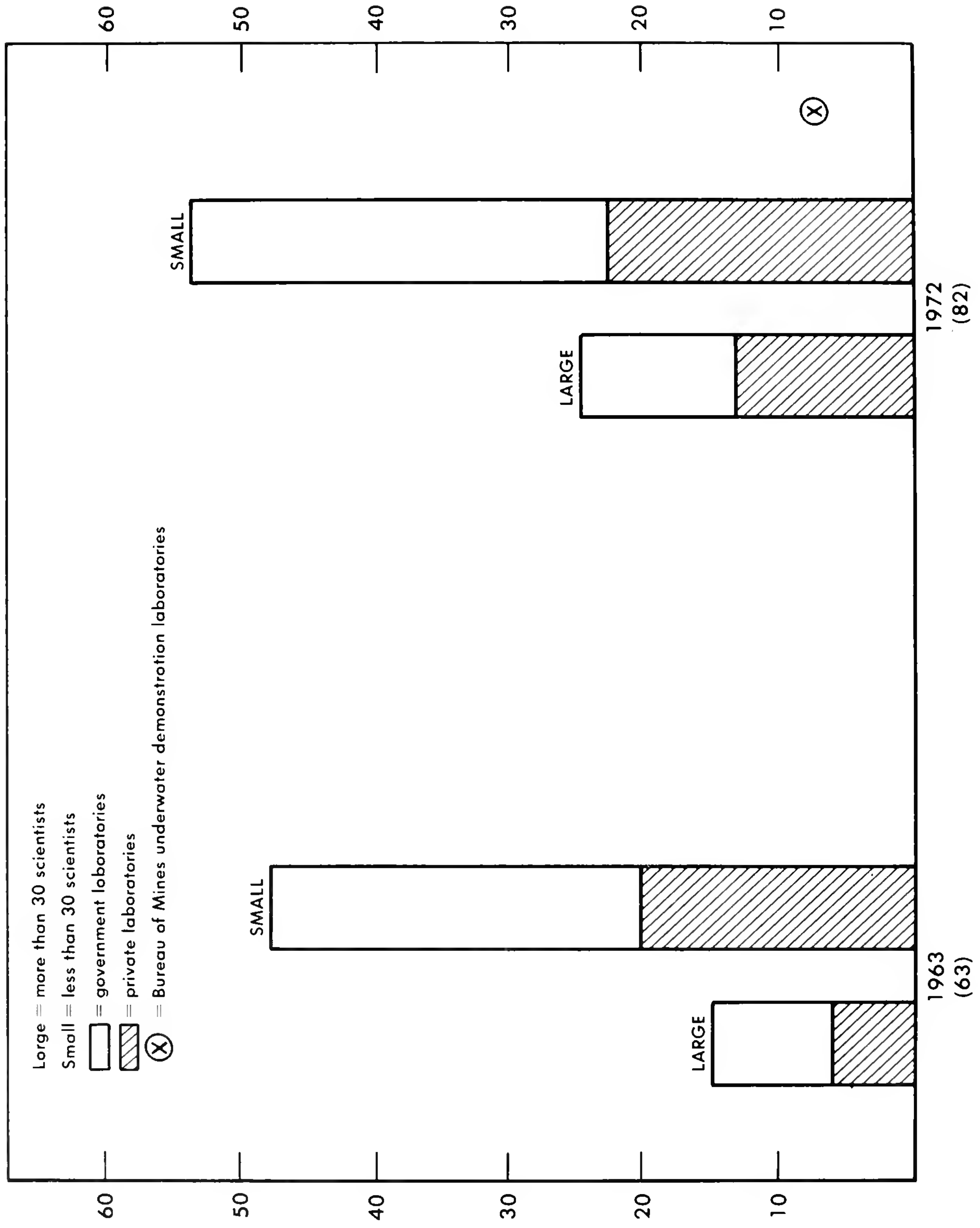


Figure 9 - Major Oceanographic Laboratories

Appendix A

RECENT BUDGET SUMMARIES

NATIONAL OCEANOGRAPHIC PROGRAM

NATIONAL OCEANOGRAPHIC PROGRAM BUDGET
(thousands)

	FY 1960	FY 1961	FY 1962	FY 1963	President's Budget FY 1964
A. BY AGENCIES					
Defense	$32,048	$31,615	$ 42,081	$ 55,246	$74,966
Commerce	6,202	11,400	23,567	24,024	24,792
Interior	6,703	8,658	14,252	16,102	18,960
National Science Foundation	7,833	7,883	17,321	18,160	25,801
Atomic Energy Commission	1,708	1,691	4,106	5,428	5,330
Health, Education, and Welfare	340	694	3,109	4,108	4,820
Treasury	134	133	134	511	1,152
Smithsonian Institution			217	431	531
	$54,968	$62,074	$104,787	$124,010	$156,352

	FY 1960	FY 1961	FY 1962	FY 1963	President's Budget FY 1964
B. BY FUNCTIONAL AREAS					
Research	$26,577	$30,860	$ 39,023	$ 46,955	$ 62,565
Instrumentation	*	850	3,000	6,630	8,878
Ships	13,533	13,998	34,010	38,103	47,665
Surveys	13,368	14,900	17,366	18,487	20,228
IIOE		760	1,974	4,002	5,854
Facilities	1,350	430	8,904	9,223	10,257
Data Center	140	276	510	610	905
	$54,968	$62,074	$104,787	$124,010	$156,352

INDIVIDUAL AGENCY BUDGETS

Agency - Function	FY 1960	FY 1961	FY 1962	FY 1963	President's Budget FY 1964
DEFENSE - TOTAL	$32,048	$31,615	$42,081	$55,246	$74,966
Navy - Total	31,492	31,077	41,593	54,621	73,892
Research	13,752	16,618	15,692	19,559	25,295
Instrumentation			2,150	5,370	6,128
Ships Construction	8,400	4,200	13,600	18,153	28,000
Surveys	9,200	9,311	9,321	9,889	11,195
IIOE		760	580	1,300	2,500
Facilities					250
Data Center	140	188	250	350	424
Army - Total	454	435	488	625	1,074
Research	454	435	488	625	1,074
COMMERCE - TOTAL	$ 6,202	$11,400	$23,567	$24,024	$24,792
Coast & Geodetic Survey - Total	6,079	11,267	23,384	23,791	24,559
Research	12	11	196	482	1,012
Instrumentation		850	850	890	1,190
Ship Construction	2,033	4,700	14,185	14,400	13,000
Surveys	4,034	5,446	7,911	7,667	7,980
IIOE					200
Facilities		250	162	272	1,036
Data Center		10	80	80	141
Weather Bureau - Total	123	133	133	183	183
Research	123	123	123	173	173
Data Center		10	10	10	10
Maritime Administration - Total			50	50	50
Research			50	50	50
INTERIOR - TOTAL	$ 6,703	$ 8,658	$14,252	$16,102	$18,960
BCF - Total	6,303	8,069	13,619	15,320	16,900
Research	6,003	5,874	7,409	9,747	11,902
Instrumentation				70	223
Ship Construction	100	2,005	3,225	2,650	3,065
Surveys				20	125
IIOE				102	154
Facilities	200	180	2,905	2,651	1,290
Data Center		10	80	80	141
Geological Survey - Total	$ 400	$ 425	$ 425	$ 494	$ 1,304
Research	400	425	425	474	520
Instrumentation				20	480
Surveys					15
Facilities					279
Data Center					10

INDIVIDUAL AGENCY BUDGETS - (Contd)

Agency - Function	FY 1960	FY 1961	FY 1962	FY 1963	President's Budget FY 1964
INTERIOR - TOTAL - (Contd)					
BSF&W - Total		154	158	238	344
Research		154	158	238	292
Facilities					52
BuMines - Total		10	50	50	412
Research			50	50	224
Instrumentation					88
Ship Construction					100
Surveys		10			
NATIONAL SCIENCE FOUNDATION - TOTAL	$ 7,833	$ 7,883	$17,321	$18,160	$25,801
Research	3,683	4,742	7,010	8,080	11,860
Ship Construction	3,000	3,093	3,000	2,900	3,500
IIOE			1,394	2,600	3,000
Facilities	1,150		5,837	4,500	7,300
Data Center		48	80	80	141
ATOMIC ENERGY COMMISSION TOTAL	$ 1,708	$ 1,691	$ 4,106	$ 5,428	$ 5,330
Research	1,708	1,681	4,096	5,418	5,312
Data Center		10	10	10	18
HEALTH EDUCATION & WELFARE - TOTAL	$ 340	$ 694	$ 3,109	$ 4,108	$ 4,820
PHS - Total	340	660	3,000	4,058	4,770
Research	340	660	3,000	1,558	4,170
Surveys				700	600
Facilities				1,800	
Office of Education - Total		34	109	50	50
Research		34	109	50	50
TREASURY - TOTAL	$ 134	$ 133	$ 134	$ 511	$ 1,152
Surveys	134	133	134	211	313
Instrumentation				300	769
Facilities					50
Data Center					20
SMITHSONIAN - TOTAL			$ 217	$ 431	$ 531
Research			217	431	531